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OPERATION WIGWAM.
Scientific Director's Summary Report.

May 1955

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October 10, 1958

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Washington, D. C. 20305

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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Operation Wigwam
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Deep Underwater Test
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Shock Wave
Radiation Dosage
Gamma
SQUAW

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report is essentially an abstract of all reports of the projects making up the Operation Wigwam Scientific Program, presented in a coordinated form. It is intended to give an overall view of the results and their meanings for the man who cannot find the time to read the project reports themselves. For the individual with specialized interests this report will be no substitute for the actual program or project reports, and in any specific field the applicable project reports should be used for computations, extrapolations, and careful evaluations.

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FOREWORD

This report has had classified material removed in order to make the information available on an unclassified, open publication basis, to any interested parties. This effort to declassify this report has been accomplished specifically to support the Department of Defense Nuclear Test Personnel Review (NTPR) Program. The objective is to facilitate studies of the low levels of radiation received by some individuals during the atmospheric nuclear test program by making as much information as possible available to all interested parties.

The material which has been deleted is all currently classified as Restricted Data or Formerly Restricted Data under the provision of the Atomic Energy Act of 1954, (as amended) or is National Security Information.

This report has been reproduced directly from available copies of the original material. The locations from which material has been deleted is generally obvious by the spacings and "holes" in the text. Thus the context of the material deleted is identified to assist the reader in the determination of whether the deleted information is germane to his study.

It is the belief of the individuals who have participated in preparing this report by deleting the classified material and of the Defense Nuclear Agency that the report accurately portrays the contents of the original and that the deleted material is of little or no significance to studies into the amounts or types of radiation received by any individuals during the atmospheric nuclear test program.

* per telecon w/Betty Fox (DNA Tech Libr, Chief), the classified references contained herein may remain.

L.E. LaChance (DDA-2)
9-5-79

*Verified for Extracted Versions, 9 July '80,
pfcooper, DTIC/DDA-2

ABSTRACT

On 14 May 1955 at 19:59.59.89 GMT, at 126°16′ west longitude and 28°44′ north latitude, a warhead (   ) was detonated at a depth of 2000 ft in 16,000 ft of water in the presence of an array of subsurface and surface targets and measuring devices.

The primary objectives of the operation, designated Operation Wigwam, were:

1. To determine the fatal range of a deeply detonated nuclear weapon for a typical, well-designed, modern submarine.

2. To determine the pressure-time field in water and in air resulting from such an explosion.

3. To determine the safe range for a surface ship in the vicinity of this detonation.

4. To determine the fall-out and contamination problems resulting.

5. To determine the characteristics of any additional phenomena occurring.

All five objectives were achieved. The evaluated data led to the following conclusions (the numbering of the conclusions corresponds to the numbering of the objectives above):

1. When submerged to a depth of 250 ft, a well-designed, modern submarine structure having a hydrostatic collapse depth of 1465 ft will be ruptured if closer than 7000 ft to the detonation of a nuclear device having a radiochemical yield of 32 kt and occurring at a depth of 2000 ft in deep (over 6000 ft) water.

For this test, a critical criterion that has been suggested (Project 3.1)* is that collapse will occur if the peak shock pressure to which the hull is subjected is given by the equation

$$P_s = 1.08\,(P_c - P_0)\,(1 + e^{-T/18})$$

where P_c is the static collapse pressure, P_0 is the hydrostatic pressure, and T is the duration of the shock pulse in milliseconds.

A second criterion[1] (see list of references at end of report) which may be less accurate, but which is applicable to a wider range of conditions, is that, if the excess impulse delivered by the shock to the submarine exceeds 2 psi-sec, collapse will result.

These criteria indicate that a light-hulled fleet type submarine (650-ft static collapse) may be expected to receive lethal damage when operating at a depth of 250 ft if a 32-kt weapon is detonated 2000 ft deep at a range of less than 14,000 ft in deep water.

2. (a) The underwater pressure-time field resulting from this explosion is similar in most respects, at ranges greater than 1000 ft, to the pressure-time field to be expected from the detonation of 46,000,000 lb of TNT. This result is in excellent agreement with the theoretical prediction received from the Armour Research Foundation (ARF) and the Naval Ordnance Laboratory (NOL). (Projects 1.1, 1.2, 1.2.1, 1.3, and 4.4)

(b) The peak pressures in the air above the shot point agree very well with values computed using normal acoustic propagation theory (1.36 psi immediately above the surface). The time constant of the air wave appears to be about 10 times the time constant given by the

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*Project references are to the project-numbered paragraphs of Chap. 3 of this report.

simple acoustic treatment. This difference is doubtless due to the rupture of the sea surface and its consequent vertical motion. (Project 4.5)

3. The very minor damage received by the YFNB-12 (range 5500 ft) is in very good agreement with the prediction based on scale-model tests made by U. S. Navy Electronics Laboratory (NEL). These tests indicated that serious hull damage to the YFNB's should not occur at ranges greater than 4000 ft. Surface ships at ranges in excess of 7000 ft should suffer only very minor damage. Minor trouble may be expected out to ranges of several miles as a result of the shock wave reflected from the bottom, rather than as a result of the direct shock wave. This minor trouble could become serious in shallower water. Under urgent conditions a surface vessel finding itself directly above a submarine could fire a nuclear depth charge off to a range of 1 mile downwind, thereby killing a submarine while sustaining only minor damage itself. (Projects 0.2, 3.2, and 3.2.1)

4. The fall-out and contamination resulting from this shot presented an ephemeral problem only. The major explosion plumes, which rose to a height of about 1400 ft and spread to a similar radius, were heavily contaminated, but the contaminated material was present in a very large mass of cold water and for the most part returned to the ocean surface promptly (within 1 min). Much of it sank below the surface and was no longer a tactical problem. The total dose at the Surface Zero was 3600 r. The principal source of air-borne contamination was the base surge (fine water droplets) that extended about 5000 ft across and upwind. This cloud drifted with the wind and resulted in a contamination level of 400 r/hr at a point 5 miles downwind in 18 min. A washdown system in operation reduced this hazard to negligible values. Contamination of surface waters spread and decayed rapidly so that by D+4 an area of some 80 sq miles was found which had a maximum level of only 1 mr/hr at 3 ft above the surface. At D+40 the only contaminated surface water located was 120 miles west of the detonation point and had a maximum level of about 10^{-2} mr/hr. Contaminated water was found at several depths during the week following the test. It tended to be in very thin sheets, only a few meters thick. One sample of this deep water was the most active found anywhere. (Projects 2.1, 2.2, 2.3, 2.4, 2.6, and 2.7)

5. The surface waves resulting from this test were much larger than anticipated. The YFNB-12, at a range of 5500 ft, rose and fell a distance of 37 ft. These figures give a range-height product of 210,000, whereas the maximum predicted was 80,000. The surface waves were undetected by the task force elements at a range of 5 miles, except that they showed up strongly on one surface-search radar which was temporarily out of adjustment. It had been knocked out of service by the shock wave, and, on being returned to service, the gain was set high so that strong sea return cluttered the scope face. The explosion surface waves modulated the sea return and were clearly visible until the radar operator returned the gain to normal and quenched the sea return. About 15 waves were visible with wavelengths ranging from 5000 ft down to 1000 ft. The maximum energy appeared in the 1800-ft region. The sea waves could have serious implications in the case of detonation of thermonuclear weapons on or under the surface of deep water. (Projects 0.31, 2.8, and 2.9)

Local valleys and hills in the sea floor caused focusing and defocusing of the bottom-reflected wave. In at least one area 15,000 ft from Surface Zero, the water was strongly whitened, indicating pressures in the neighborhood of 500 psi, which is about those expected at 7000 ft and enough to cause collapse of light-hulled submarines. At other places, such as some of the gauge positions, the bottom-reflected shock appeared to be missing completely. At the USS Mount McKinley (AGC-7), the bottom-reflected shock was several times as intense as the direct wave (5 miles). (Project 1.5)

The sounds were well perceived through the hulls of surface ships at considerable ranges. A Greek ship just off the Golden Gate radioed the Coast Guard at San Francisco asking if that city had just been hit by a severe earthquake. The ship had been badly shaken but was undamaged and would render assistance if needed! The time was 1312 PDT on 14 May 1955.

The seismic shock was easily detected all over the world, and the U. S. Coast and Geodetic Survey (USCGS) reported an earthquake at 20:00.00Z on 14 May with epicenter at 29°N and 126½°W. The USCGS indicated that the time was accurate! Professor P. Byerly of the University of California, Berkeley, stated that either the time was in error by 4 sec (shot late) or the

position was in error by 15 miles radius from Berkeley (greater) on the basis of the records he obtained alone. The position determined by ships' navigators was 28°44'N, 126°16'W, agreeing excellently with Prof. Byerly's estimate.

The sofar equipment at Point Sur, Calif., received a beautiful echo from the Hawaiian Islands. The Kaneohe Station in Hawaii got fine echoes from the California coast and also from the Gulf of Alaska.

Finally, not one dead or stunned fish or mammal was observed as a result of the explosion from any task force ship, boat, or plane. This may be the result of two circumstances: first, fish in the area were scarce, as described below; and, second, it is highly probable that a shock wave having the slow decay of this one may be lethal to fish at extremely short range only. Ten days of fishing using long-line techniques resulted in a total catch of 15 sharks, 1 snake mackerel, and 1 opah, none of commercial value and none showing any radioactivity. The monitoring program of the California fish canneries produced only one contaminated fish, which proved to be a Japanese import and probably contaminated by Operation Castle. The tuna industry took the attitude that, if the Scripps Institution of Oceanography had determined the place for the detonation, there was no need to worry. (Project 2.5)

Recommendations.

1. Using scaled explosions and targets, studies should be made to determine safe and fatal ranges for various types of submarines and surface vessels.
2. Previous estimates of optimum warhead yields and explosion depths should be reevaluated in the light of the Wigwam results.
3. Scaled experiments should be performed to extend and improve the estimates of wave production by explosions. The results obtained may critically affect the use of thermonuclear weapons.
4. Marked reduction of the hull-splitting range for submarines may result from increased collapse depth and radical design concepts which should receive careful study.
5. Should additional tests of this nature become necessary, the area used appears excellent from the standpoints of international and fishery relations. If anticipated, the weather and sea conditions are not prohibitive.
6. It will probably be necessary to check safe ranges for delivery vehicles and refraction effects by additional full-scale tests.

PREFACE

This report is essentially an abstract of all reports of the projects making up the Operation Wigwam Scientific Program, presented in a coordinated form. It is intended to give an over-all view of the results and their meanings for the man who cannot find the time to read the project reports themselves. For the individual with specialized interests this report will be no substitute for the actual program or project reports, and in any specific field the applicable project reports should be used for computations, extrapolations, and careful evaluations.

The successful outcome of Operation Wigwam would not have been possible without the foresight of those responsible for the preliminary planning that began almost five years prior to the final experiment. The fact that nearly every project provided the data required to give positive answers to the questions under investigation, in the face of nearly insuperable difficulties presented by the wind and seas, is proof of the value of careful planning and of careful preparation of the measuring equipment. The only failures to obtain informative results occurred in those projects in which the equipment was not completed in time to make thorough field tests prior to the final operation. The policies of equipment backup, mixing types of information passing through each cable, paralleling telemetering channels, local recording, using magnetic tape wherever possible, and full photographic coverage paid off in every case. The integration of scaled experiments with the prototype test provided full information coverage at a saving of many millions of dollars. It is to be hoped that these obviously important factors will be kept in mind in future test planning.

ACKNOWLEDGMENTS

The author wishes to express his conviction that the entire personnel taking part in Operation Wigwam were the finest group of men with whom he has been associated in over 15 years of work with the U. S. Armed Forces. Where all were so cooperative and did their assigned tasks so much better than could have been expected, it is impossible to single out a few for special credit without slighting many who were equally deserving. One, however, does merit particular mention, namely, CAPT John H. Lofland, Jr., CEC, USN, for his untiring work as Deputy Scientific Director.

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Chapter 1

BACKGROUND AND PREPARATION

1.1 OPERATION WIGWAM

Operation Wigwam is the code name of the first deep underwater nuclear explosion in history. The explosion took place in a lonely part of the Pacific a few hundred miles west southwest of San Diego on 14 May 1955. The weapon, a [redacted] was exploded at a depth of 2000 ft in 16,000 ft of water, in the presence of an array of subsurface and surface targets and measuring devices.

The detonation was made by agencies of the U. S. Government for test purposes, the primary objectives being (1) to determine the fatal range of a deeply detonated nuclear weapon for a modern submarine and also the safe range for a surface ship; (2) to plot the pressure-time fields in water and air; (3) to study the fall-out, contamination, and any additional phenomena.

1.2 EARLY CONSIDERATION

The project had a long and checkered history, the early part of which is covered only very briefly in this chapter. Considerably more detail of the early historical background is given in Appendix B.

A deep underwater explosion was first considered by the Manhattan District in 1944 but was shelved in favor of higher priority detonations. By 1946 three successful atomic detonations had been made, namely, Trinity, Hiroshima, and Nagasaki, but it was evident that much information was still lacking. At about the same time, public interest was keen as to the effects of an atomic bomb on ships, and the Joint Chiefs of Staff appointed a committee, the Joint Staff Planners, to determine what tests should be made, if any, and by whom. The Joint Staff Planners recommended that an atomic bomb should be exploded deep in the ocean, but they listed this test lower in priority than detonations high in the air and just above or below the surface of the water. Arguments for and against the deep underwater test were advanced, and preliminary specifications for it were outlined; however, in September 1946, the President cancelled such a test indefinitely.

1.3 REVIVAL OF INTEREST

By 1951, interest had revived, and, at the request of the Chief of Naval Operations (CNO), the Pelican Committee (of scientists) was organized to aid the Chief, Armed Forces Special Weapons Project (AFSWP), in deciding whether a deep underwater test was necessary and, if

so, to recommend its scope. The Pelican Committee in 1952 recommended a full-scale test and concluded that it would entail a two-year period of development and preparation. Later that year the Chief, AFSWP, formed an *ad hoc* committee of naval officers to amplify and extend the work of the Pelican Committee. The *Ad Hoc* Committee established a formal objective for the test, outlined target and instrumentation needs, estimated costs (at about $32,000,000 exclusive of ship targets), and suggested four possible sites. In December 1952, AFSWP was formally directed by the Joint Chiefs of Staff to plan and prepare the test. The Special Field Projects Division of AFSWP began operating January 1953, and its Wigwam Planning Group planned a test to cost about $36,000,000.

1.4 PRELIMINARY PHASE BEGINS

Economy considerations by a new administration reduced the scope of the test and, by the end of the year, a reduced program to cost about $12,000,000 including targets was approved by the Secretary of Defense, after review of the program by the three services and the AEC. At the request of the Wigwam Planning Group, the Bureau of Ships (BuShips) was already conducting studies on floats, instrumentation, submerged targets, etc., the Navy Electronics Laboratory (NEL) was preparing proposals for a free-field instrumentation system, and the David Taylor Model Basin (DTMB) was evaluating various proposed handling techniques for the target array.

1.4.1 Test-site Preliminary Studies

(a) *Location.* Of the four sites suggested by the *Ad Hoc* Committee, the one in the vicinity of the Galapagos Islands was eliminated by the State Department because of possible difficulties which might arise with the Ecuadorian Government.

An expedition by the Woods Hole Oceanographic Institution (WHOI) into the proposed area of the Caribbean proved that the currents there were so high and unpredictable that contaminated water would probably appear on foreign shores within two days.

The Eniwetok-Bikini area was eliminated on the basis of its remoteness from base facilities and the predictable high winds, seas, and swells expected in the area.

Therefore the site most suitable for Operation Wigwam, in the opinion of the Wigwam Planning Group, was the remaining proposed area, namely, that part of the eastern Pacific Ocean lying within the sector bounded by rays south and southwest of San Diego, Calif., and beyond the 1000-fathom line.

(b) *Meteorology.* During the month of May 1954, a meteorological study of the proposed operating area for Wigwam was conducted at the Fleet Weather Central, San Diego, Calif. This study was scheduled for the same time of year as the test and involved operation of air-borne sea and swell recorders, special surface observations from ocean vessels, and simulation of other data-gathering facilities, as well as trial operation of data transmission facilities. On the whole, the information obtained during this study was very encouraging except for the amount and altitude of cloud cover. Wind and sea conditions approached the ideal to be expected in the open seas. The maximum wind recorded reached 15 knots only once during the study, and then for several hours only during one day. Cloud cover, however, was greater than ⅞ continuously, and ceilings were generally lower than 5000 ft. These cloud conditions prevented planning for high-altitude photographic coverage of the array and of surface effects of the explosion. They also increased the importance of planning for the minimum number of aircraft to be employed in the test area at any one time and of ensuring that excellent all-weather aircraft-control facilities be available.

(c) *Oceanography.* The Scripps Institution of Oceanography devoted increased attention to the planned test area during the spring of 1954. Special cruises were made to the test area during the same time of year planned for the test, and general oceanographic data gathered elsewhere were correlated with the increased fund of detailed data compiled for the test area. As in the case of the weather studies, the oceanographic information which was assembled

confirmed earlier estimates of the suitability of the area for the test. Broadly speaking, the chosen area (south to southwest of San Diego, Calif., at a distance of between 200 and 600 miles from that base) was again found to approach the ideal, except for the problem of lack of dispersion. In that respect it appeared that a volume or surface area of contaminated water would tend to increase in size much more slowly in the chosen test area than was believed to be the case in the open sea. This possibility made it necessary to plan for surveillance of the contamination for a much longer period than might have been necessary elsewhere. On the other hand, a well-defined area of contamination would be easier to track and, thus, an easier area from which to avert shipping. Aspects of the oceanography of the area which made it favorable for the deep underwater nuclear detonation were:

1. A stable water current of very low magnitude, with small velocity and directional shear with depth.
2. Generally small wind velocities and consequently low sea states.
3. Adequate ocean depth.
4. A "line of divergence" north and south through the area, such that (1) water west of the line would touch a shore line only after thousands of miles of travel and (2) the fish population west of the line would be too sparse to be commercially interesting.

(d) *Radiation Hazard. Sea Life Contamination.* On 1 November 1954 a meeting was held in the office of Dr. C. L. Dunham, Division of Biology and Medicine, AEC, to explore approaches to the problem of monitoring commercial tuna fish catches and tuna fish packing activities on the West Coast of the United States. As a result of discussions at this meeting and of previous discussions with a representative of the Inter-American Tropical Tuna Commission, it was generally agreed that the likelihood of the contamination by Operation Wigwam of commercial fish, to a point where a health hazard would be present, was nil, and, further, that the chance of contaminating to an appreciable or hazardous extent any tuna appearing on the West Coast was very small. After full consideration of these problems it was agreed: (1) that the AEC would make every effort to establish criteria as to maximum permissible levels of activity in commercial fish which the AEC would be willing to defend publicly if necessary, and (2) that the AEC, through the Pure Food and Drug Administration, would advise and assist the tuna fish canners in such a way as to enable them to monitor their own catches and to set up such monitoring systems on a continuing basis.

Radiological Safety. As part of the planning for Operation Wigwam it was necessary to develop an extensive radiological safety program. The services of the U. S. Naval Radiological Defense Laboratory (NRDL), San Francisco, Calif., were utilized for this purpose. Authorization was obtained from the AEC to permit the Oak Ridge National Laboratory and the University of California Radiation Laboratory to make health physicists available to NRDL to augment its staff of health physicists during Operation Wigwam. Project Officers for Operation Wigwam were requested to submit a list of those persons who received nuclear radiation exposure during the calendar year 1954 and to include remarks such as a record of limitations of assignment because of the exposure.

(e) *Explosion Bubble.* Considerable uncertainty existed concerning the nature of the growth and collapse of the gas bubble to be generated by the explosion. New York University was requested to make a theoretical prediction of the bubble development and recollapse. This study was able to follow the cavity collapse to the point when the bottom jet reached a point midway between the center of the original bubble and its upper surface.[2] At about this point the solution broke down.

1.4.2 Targets, Preliminary Studies

One of the major objectives of the test was to ascertain the maximum range at which hull-splitting damage to a submerged typical submarine at a single depth could be assured. Another important objective was the determination of the influence on delivery tactics resulting from surface effects and particularly from the standpoints of hull-splitting and internal shock damage.

(a) *Required Characteristics of Submarine Targets.* On 17 June 1953 the Wigwam Planning Group formulated the following criteria for the target array:

1. The targets should be identical.
2. They should lend themselves to economical and safe handling techniques in an array at sea.
3. Each target should be a gauge, of understood performance.
4. The targets should meet the demands of economy imposed on the test.
5. They should be large enough in pressure-hull diameter so as not to be small-scale targets.
6. They should be built of modern type steel of a thickness of material typical of that of naval submarines.

Each type of target that might be available for the test was considered in the light of these criteria.

(b) *Choice of Target Type.* In reply to the AFSWP request, in May 1953, for studies and cost estimates in regard to the target best suited to Operation Wigwam, BuShips recommended that a full-scale submarine be chosen for the test. This recommendation was based on advantages in cost, in applicability of results, and in determining reliable shock effects. A disadvantage lay in the difficulty of handling. The Bureau's estimate of cost failed, however, to take into account the replacement cost of a full-scale, inactive fleet submarine, which burden would have to be borne by the AFSWP and for which funds had not been provided in the budget estimate. Furthermore, the purpose of the deep underwater test, as stated by the Secretary of the Navy, was to obtain information concerning the maximum range at which hull-splitting damage to a submerged typical submarine at a single depth would be assured. Provision had not been made for determination of a lethal shock-damage range. On 26 August 1953, in a letter to CNO, the Chief, AFSWP, noted that the choice of targets by BuShips rested upon an assumption that full-scale targets were available for use in Operation Wigwam and that no expenditure of funds was assumed to be required for the repair or replacement of full-scale targets. It was pointed out that the approval of Congress would have to be obtained for the use of the recommended targets and that, in addition, preliminary discussions with interested offices of CNO indicated that difficulty might exist in obtaining full-scale targets. For these reasons this type target was eliminated from further consideration.

(c) *SQUAW Targets.* Target prototypes with specially constructed hulls similar to the K class hull, but with internal framing, capsule ends, and a minimum of structural discontinuances, were deemed by the AFSWP and its Wigwam Planning Group to be best for the test. The concurrence of CNO was granted 3 October 1953.

The proposed target was a prototype of the SS-563 class submarine with a $14\frac{1}{2}$-ft pressure-hull diameter constructed of 1-in.-thick HTS plate. For economy in fabrication, all shell elements were one-dimensional bends. The total displacement would be about 400 tons. Engines would be simulated by cast-iron mass weights, and batteries by concrete masses. These targets were dubbed SQUAWS.

(d) *Handling Feasibility of Target Type Chosen. Model Basin Test.* DTMB conducted feasibility studies of handling techniques for pontoons, lighters, and $\frac{1}{13}$-scale targets. At the end of 1953, towing tests were under way at DTMB; they were completed during February 1954. These trials proved the feasibility of suspending the submerged target from submarine rescue pontoons. They also proved that the target-pontoon-instrument float complex could be successfully towed and handled under ideal sea conditions.

Model Sea Test. As an intermediate step between model and full-scale testing, it was considered highly desirable to conduct an operational test of a $\frac{1}{3}$-scale target. Since this could be accomplished by utilizing the $\frac{1}{4}$-scale model of the SSN-571 in the custody of the Underwater Explosions Research Division (UERD) of the Norfolk Naval Shipyard, a test plan was submitted to CNO, on 20 November 1953, with the request that the Commander of the Service Force, Atlantic Fleet, be designated to undertake such a test as an evaluation project for the AFSWP. It was suggested that this test be conducted off the Virginia coast in May 1954. On

11 December 1953, CNO directed the Commander-in-Chief, Atlantic Fleet, to provide the necessary services for conducting this scaled test. The complex was successfully controlled under sea conditions that scaled extreme storm conditions for the Wigwam elements, thus proving the rigging philosophy and justifying the completion of definite plans for the full-scale operation.

Simultaneously other operational problems were resolved, and plans were published in the Operation Wigwam Concept[3] which was distributed 21 April 1954.

(e) *Theoretical Analyses.* Prior to the operation, analytical studies were performed by several groups in an endeavor to predict, from a mathematical approach, the damage the SQUAWS would receive. At a planning conference in March 1955, each of the activities submitted a final estimate of the collapse pressure (lethal range) for the SQUAW targets. These predictions are listed in Table 1.1. These predictions turned out to be in good agreement with the results of the operation.

TABLE 1.1—ESTIMATED LETHAL RANGES FOR SQUAW TARGETS

Author	Total peak pressure, psi	Assumed yield stress, psi		Range, ft
		Dynamic	Static	
Bleich (Col. U.)	760	59,000	52,000	8000
Hoff et al (PIB)	810	60,000	52,500	7400
Carrier (Brown U.)	840		52,000	7100
Newmark (U. of Ill.)	860	56,000	52,000	7000
Gooding et al. (DTMB)	880	70,000	59,000	6800
Kiel (UERD)	950	58,000	58,000	6300

1.4.3 Target Construction

After careful review by the Long Beach Naval Shipyard and because of proximity to San Diego and the availability of a large floating crane, on 9 October 1953, the AFSWP requested BuShips to construct two targets at Long Beach; a third target was ordered after a budget increase was approved by the Secretary of Defense on 8 December 1953. Construction of the targets for Operation Wigwam was begun at the Long Beach Naval Shipyard early in the year 1954. Production progress and control, and construction techniques, were excellent. Production control involved extensive laboratory engineering tests of the steel for the pressure hull and then the placing of plates of similar characteristics in matching positions in the three targets. Alterations of the three lighters (YFNB's) for use as instrumentation floats were accomplished at the San Diego Naval Repair Facility.

1.4.4 Administration

Logistics and organization of Operation Wigwam are detailed in Operation Wigwam Concept.[3] Basically, the Wigwam Planning Group (Special Field Projects Division) was to form the nucleus for a task group staff. Air support, surface patrol, surface support, base support, and scientific units would make up the task group.

1.5 PRELIMINARY PHASE COMPLETED AND PREPARATORY PHASE BEGINS

By the middle of 1954, many of the tasks remaining to be performed prior to the operational phase were organizational and operational by nature. Therefore the Chief, AFSWP, recommended to CNO that the remainder of the preparatory phase be redesignated the "preoperational phase" and that the responsibility for conducting the operational phase of Wigwam be transferred to the Commander, Joint Task Force Seven (CJTF-7). CNO concurred, and on

24 November 1954 the responsibility for the operational phase was assumed by CJTF-7. Meanwhile, on 16 November 1954, the Special Field Projects Division, AFSWP, moved its quarters to the Naval Gun Factory, Washington, D. C., where JTF-7 was quartered. Special Field Projects remained, however, a Division of Headquarters, AFSWP, and no changes were made in the basic organization and support policies for the Division in respect to its relationship with the AFSWP.

1.5.1 Expenditure of Fissionable Material Approved

Formal approval for conducting Operation Wigwam and for the expenditure of the fissionable material required was requested in a joint letter of the Department of Defense and the AEC to the President on 6 December 1954. The approval was granted by the President on 9 December 1954.

1.5.2 Key Events

With the conclusion of the preliminary phase, many key events remained to be completed:

1. 15 July 1954: Construction of first target completed. Pontoons, chains, air hose, and tow cable on hand for test by Long Beach Naval Shipyard.
2. 15 August 1954: First YFNB rigged and ready at Long Beach for test with target.
3. 1 October 1954: First target tested by Long Beach Naval Shipyard. Weapon support barge and weapon case ready for testing.
4. 22 October 1954: All targets completed, tested, and delivered to San Diego.
5. 22 October to 22 December 1954: Surface Support Unit conducts handling tests of targets, YFNB's and pontoons off San Diego.
6. 15 November 1954: Weapon support barge completed.
7. 8 January 1955: Full-scale test of array off San Diego, all units of Surface Support Unit participating.
8. 17 January 1955: YFNB's ready for project trailers. All project trailers due at San Diego.
9. 14 February 1955: YFNB's complete; all project trailers on board. Instrument leads from targets to YFNB's installed, ready for ring-out. USS Mount McKinley (AGC-7) and USS Curtiss (AV-4) available at San Diego.
10. 11 April 1955: All target instrumentation completed.
11. 1 May 1955: All array components and experimental equipment tested and ready.
12. 2 May 1955: Deploy to test area.
13. 7 May 1955: Commence rigging array.
14. 11 May 1955: Scheduled shot date postponed to 14 May 1955.
15. 14 May 1955: Shot date.

The preoperational phase extended from 15 November 1954 to 31 March 1955. The operational phase was from 1 April to 28 May 1955.

1.5.3 Target Handling Trials

During the period 25 to 27 October 1954, the lighter (YFNB), SQUAW-12 (target) array unit was subjected to handling trials off San Diego. In general, the submergence and emergence test on SQUAW-12 was satisfactory. The Commander, Service Squadron One, was present to observe the lowering and raising operation, and while at the test site he discussed preparations for the full-scale array test, scheduled for the period 10 to 22 January 1955.

1.5.4 January Handling Trials

On 12 January 1955 the Wigwam array, consisting of SQUAWS, associated submarine-salvage pontoons and instrument-barge YFNB's towing wire, instrument float LCM's, and YC zero weapon barge was taken to sea in the fleet operating area off San Diego for a towing test of the array prior to deployment for the operational phase of Wigwam. The operation was conducted by the Commander, Task Group (CTG) 56.1 (Commander, Service Squadron One),

with CJTF-7 and CTG 7.3 embarked in the USS Curtiss (AV-4) observing the progress of the towing trials.

At the conclusion of the towing trials on 14 January 1955 the instrument and air-hose bundle was discovered to have pulled out of the bow of SQUAW-12, which was thus fully flooded. This required a full-scale salvage operation at White Cove, Santa Catalina Island. The complete operation of taking the array to sea, the hookup, instrumentation, towing, and disassembly were considered generally successful.

As a result of the January handling trials it was considered necessary to conduct further tests in an effort to perfect the drogue which was trailed off the YC zero barge. Various sizes of parachutes were tested at sea during the following several months, the most successful of which was a specially designed "ring-slot" parachute. This drogue provided the necessary drag to slow down and stretch out the array and further assisted in stabilizing the rolling and pitching of the YC Zero Barge.

Various scientific projects participated in these trials with the general purposes of familiarization of personnel with sea conditions and handling problems and exposure tests of equipment. Generally, project participation was highly successful.

1.5.5 Wigwam Planning Draft Distributed

On 2 March 1955 CTG 7.3 issued the Planning Draft of CTG 7.3 Operation Plan 1-55.[4] This draft was submitted to CJTF-7 for approval and to the prospective task unit commanders for comment and recommended changes.

1.5.6 Scientific Director's Brief to AEC, 15 March 1955

A summary of the Scientific Director's statements is as follows:

1. There will be no seismic or earthquake effects felt except by sensitive seismographs.
2. There will be no tsunami or tidal waves or, in fact, any measurable surface waves at distances greater than 5 to 10 miles.
3. There will be no significant air-borne contamination except possibly in the immediate vicinity of Surface Zero.
4. The water-borne contamination will decay to very safe levels before approaching any shore.
5. The danger of any food fish becoming contaminated is very slight. Certainly no large number of them will be contaminated, and, if any are, they will probably be isolated individuals. There still remains the small chance of catching any particular fish, whose contaminated parts would be further diluted prior to commercial use.

In conclusion the Scientific Director thought that a monitor program of fish catches should be instituted because of the Operation Castle hot lake and other future Pacific tests and that this program should be capable of reducing the danger which is already at the vanishing point.

On 7 April 1955 the Chairman of the AEC notified the Chairman of the Military Liaison Committee that, relative to a request by CTG 7.3, preparations were being made by AEC, in cooperation with the Food and Drug Administration, whereby fish catches at certain West Coast ports could be checked on a sampling basis.

1.5.7 Order for Conduct of Operation Wigwam

On 15 March 1955 CJTF-7 informed CTG 7.3 that CJTF-7 assumed over-all responsibility for the conduct of Operation Wigwam and would supervise the execution thereof. Furthermore, CJTF-7 would act as the senior representative of the AEC in the exercise of functions designated by the Commission.

CTG 7.3 was directed on 15 March 1955 by CJTF-7 to accomplish the following:

1. Execute plans for Operation Wigwam to conduct a weapons effects test involving the detonation of one atomic weapon at deep submergence in order to (1) determine and evaluate the response of three targets submerged to the same depth, but at various ranges, so as to obtain information from which a prediction can be made of the maximum range at which lethal

hull-splitting damage to a typical submerged submarine can be assured, (2) determine the peak pressure and pressure-time fields, (3) evaluate the surface effects with particular regard to their influence on delivery tactics, and (4) determine the equivalent yield of the weapon used, the dispersion of radioactive contaminants, and the oceanographic factors affecting transmission of the shock wave.

2. Conduct Operation Wigwam at least 50 miles from the nearest land within the general area from south to southwest of San Diego, at a distance from that base of between 200 and 600 miles. This area may be extended to include an area between southwest and west of San Diego at the same distances should oceanographic studies indicate more favorable conditions exist therein. The test will be conducted in a manner designed to eliminate all hazard to the mainland and Guadalupe Island. Adequate security measures will be taken to ensure against entry into the danger zone by random shipping and aircraft.

3. Integrate into TG 7.3, and exercise operational control of, the assigned naval forces, forces as may be made available by the other military departments, and assigned AEC facilities and personnel.

4. Report directly to Commander-in-Chief, Pacific (CinCPac) for movement control, logistic support, and general security of the Wigwam test area and the task group.

5. Advise CinCPac of the special hazards and danger areas involved and of the precautions and emergency measures required to ensure safety of all persons in the test area.

6. Ensure that, within TG 7.3, there is no deliberate publicity in connection with the operation.

7. Upon completion of Operation Wigwam submit to CJTF-7 a report of the activities of TG 7.3 and of the results of the test programs.

1.5.8 Operation Plan and Order Distributed

On 25 March 1955 CTG 7.3 distributed the CTG 7.3 Operation Plan 1-55. Upon receipt of this final plan the task unit commanders prepared respective detailed plans pertaining to the operation of their units. The task group plan covered the period of operations from the time the major elements of TG 7.3 were assembled on the West Coast until 22 April 1955, when all task units were activated for operations. At this time the operation plan became effective as an operation order.

1.5.9 Explosion Shock Tests

Commencing on 14 April 1955 and continuing for a period of one week, explosive shock tests of the instrumentation of the YFNB-SQUAW array units were carried out at the U. S. Naval Repair Facility, San Diego, employing 10-lb TNT charges. Timing and firing of the charges was accomplished from the USS Mount McKinley (AGC-7).

1.5.10 Radar Tracking Exercises and Communication Interference Tests (18 to 21 April 1955)

Under the direction of CTG 7.3, radar tracking exercises and communication interference tests were conducted off San Diego, from 18 to 21 April 1955 by components of various units of TG 7.3.

Owing to unfavorable wind and sea conditions, the events requiring the services of LCM type boats were postponed from the scheduled dates to 21 April, when the underway units would be in an area where more favorable sea and wind conditions were expected. On 21 April 1955, all units involved had arrived at an area 70 miles westward of the original area. In this area the sea and wind conditions were favorable enough to conduct the remaining events, and the additional time permitted reruns of the other events except those involving aircraft participation.

This underway test and exercise period proved most beneficial in that problems encountered with radio interference on the telemetering and firing-and-timing circuits due to frequency proximity, antenna location, and transmitter power output were readily located and

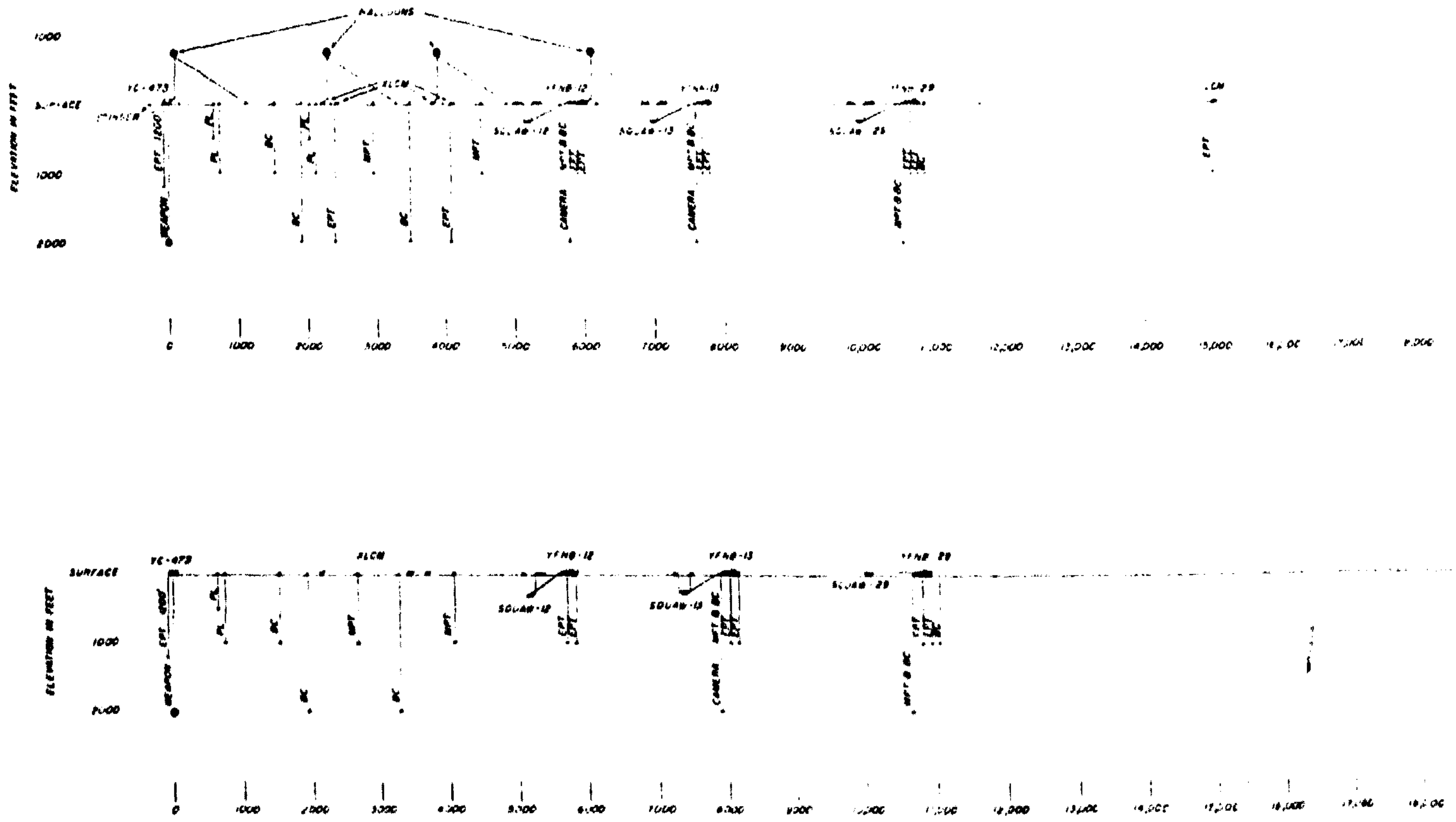

Fig. 1.1 — Operation Wigwam array. Top, as planned. Bottom, actual.

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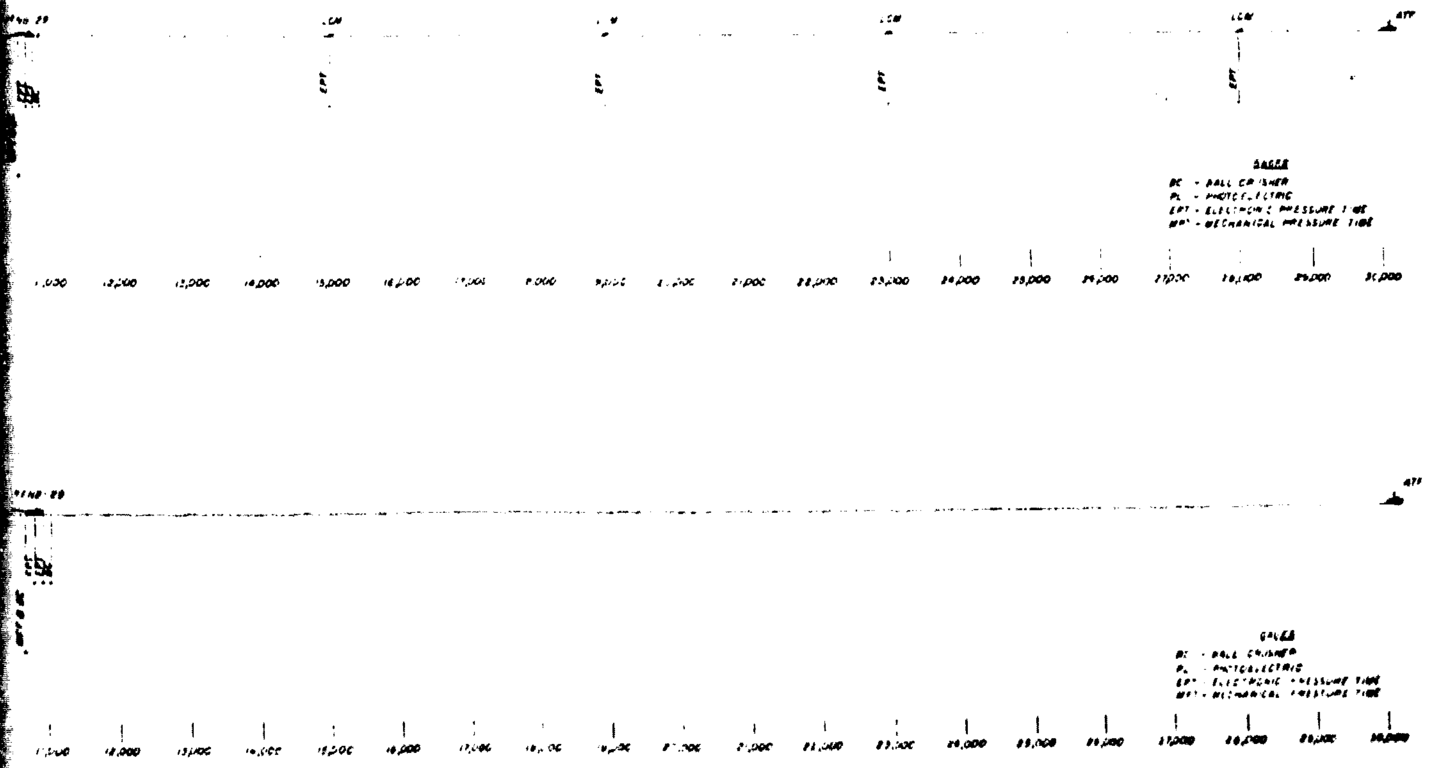

Fig. 1.1 — Operation Wigwam array. Top, as planned. Bottom, actual.

2

resolved. In addition, difficulties were experienced by the destroyer picket (DDR) radars in tracking C-54 aircraft for radar photography. These difficulties, which were due to ship superstructure interference and to deck and train plane limitations of the Mark 37 GFCS radar, were resolved by assigning Mark 56 GFCS radars to near azimuth radar photo targets and by assigning Mark 37 GFCS radars to targets of the greater lineal distance from the tracking ships.

1.6 CONDUCT OF OPERATION WIGWAM

1.6.1 Hydrographic and Aerological Missions Mounted (D−30)

On 12 April 1955, D−30, the Hydrographic Survey Element, Task Element (TE) 7.3.5.4, composed of three P4Y-2 aircraft under the technical control of Task Group Weather Central, Naval Air Station (NAS), North Island, San Diego, commenced conducting hydrographic missions for the purpose of assisting in determining the hydrographic and aerological conditions existing and to be expected in the test area. Concurrently, Scripps Institution of Oceanography vessels were continuing pelagic and oceanographic surveys of the proposed test area for the purpose of recommending a definite test location prior to the arrival of TG 7.3 in the area.

1.6.2 Activation of Task Units, 22 April 1955

With all major elements of TG 7.3 being assembled on the West Coast, CTG 7.3 activated for operations all task units on 22 April 1955. These units then operated in accordance with CTG 7.3 Operation Order 1-55, which was formerly CTG 7.3 Operation Plan 1-55.

1.6.3 Deployment Begins, 2 May 1955

Deployment from West Coast ports commenced on 2 May 1955 when YAG-39 and YAG-40 departed from San Francisco. The Molala departed San Diego on 3 May and rendezvoused with the YAG's for training exercises prior to joining the main body.

On 3 May the Surface Support Unit departed San Diego and, escorted by six destroyers of the Surface Patrol Unit, proceeded to a predesignated rendezvous point. On 4 May the destroyers formed a scouting line and swept the area surrounding the expected detonation point. The following day they established a surface patrol with a radius of 30 miles about the site.

The remaining heavy ships departed San Diego on 5 May, one destroyer providing a screen for the Curtiss, continually, until the nuclear components were off-loaded to the YC on 13 May. All units, less the destroyers on patrol and one destroyer which remained in Long Beach to provide transportation for CJTF-7, joined on 6 May and proceeded in company thereafter to the test site.

1.6.4 Wigwam Complications Begin

As originally planned, all elements of the array were to be positioned as shown in Fig. 1.1. Each of the three targets was to be suspended from eight submarine salvage pontoons at a depth of 250 ft by means of $2\frac{1}{2}$-in. die-locked anchor chain. Many of the instrument gauges were to be suspended from LCM's and buoys within the array, and helium balloons were to be raised above various array elements for air overpressure measurements. Likewise, a drogue was to be used astern of the YC to aid in stretching out the array.

During transit from San Diego, however, continued high winds and seas took an exacting toll of the array elements. One by one the SQUAW units deteriorated. Breaks in instrument leads were first discovered, followed in turn by air-hose ruptures, pontoon bilging, and chains parting; the targets were still being towed on the surface.

By 9 May, the day on which it had been planned to commence assembly of the complete array, three chains of SQUAW-29, the forward port chain of SQUAW-13, and both after chains of SQUAW-12 had parted. Many of the pontoons had holes and were listing badly; several had actually been carried away in the heavy seas.

1.6.5 Underway Repairs

On 10 and 11 May the weather abated sufficiently to permit the launching of boats, and a general rehabilitation program was inaugurated. The after starboard chain of SQUAW-12 had parted by this time. All remaining chains to SQUAW-29 were burned off, and the pontoons were disconnected. In lieu of broken chains on the other two SQUAWS, $1\frac{7}{8}$-in. wire was rigged. Wire was also run completely around several of the pontoons in an effort to maintain a submergence capability. Only by heroic efforts of personnel of the Towing and Salvage Element and Boat Pool Elements under extremely adverse conditions was it possible to prepare any of the SQUAWS for insertion into the array.

While making preparations for launching LCM's on 10 May, at about 1545, the backwash from an unusually large swell lifted the stern gate of the USS Fort Marion (LSD-22) within 2 ft of the closed position. The stern gate was being lowered at the time and was within 1 ft of being fully open. The next swell lifted the stern of the ship rapidly, causing the water to rush out the stern of the well and forcing the stern gate to open rapidly and slam down hard. This blow parted both the port and starboard $1\frac{7}{8}$-in.-wire lowering pendants and stranded the $1\frac{3}{4}$-in.-wire preventer. After the LCM's were launched, another swell caused the stern gate to raise about halfway and then slam down, parting both $1\frac{3}{4}$-in.-wire preventers and allowing the stern gate to drop to the vertical position. At about 1600 the gate wrenched itself free and fell off. At the time of the casualty the ship was on course 350°T at 4 knots heading into 6- to 12-ft swells. Wind and sea were from 0.35°T, with the wind velocity 10 knots. Loss of the stern gate, however, did not deter the Fort Marion from continuing her mission in support of Operation Wigwam, an accomplishment that indicates excellent qualities of seamanship on the part of the personnel concerned.

1.6.6 Assembly of Array, 12 May 1955

Assembly of the 5-mile array was commenced on 12 May. The two LST's streamed their wire and buoys, helium balloons were inflated, and instrument-boat LCM's from the Fort Marion were launched preparatory to insertion into the array. Only one of the LCM's scheduled for stations between YFNB-29 and the tow tug could be secured in position due to the delay caused by the casualty to the USS Comstock (LSD-19), described later, and this boat broke loose from the array on 13 May and was taken in two by the USS Butternut (AN-9). Of the four instrument LCM's attached to the tow wire between the Zero Barge and YFNB-12, one broke loose at 0945 on 14 May, and the instrumentation on the other three was inoperative.

On 13 May the remainder of the array was assembled and took course 000°T, speed about 0.5 knot. SQUAWS 12 and 13 were submerged and positioned at ranges of 5200 and 7300 ft, respectively, from the YC, and SQUAW-29 remained on the surface at 10,100 ft. During the day the weather again worsened, with additional damage occurring to the array elements. The balloons raised from the Zero Barge, YFNB-12, and instrument LCM A-2 were cast loose to prevent further damage to installed antennas. The wires by which the after portion of SQUAW-12 was being supported parted, leaving the entire target suspended only by the two forward chains and with an up-angle of 34°. The towing wire between the SQUAW-13 pontoons and its YFNB parted, and attempts to rig a wire between the two were unsuccessful, leaving the entire array under tow through the 2-in. wire to the submerged SQUAW. An 8-in. manila line was hurriedly rigged, but it soon parted because of the heavy strain. A second 8-in. manila line was then rigged, along with a 9-in. manila line, and these lasted until the morning of 14 May when they too parted, as did the line to the last remaining helium balloon. At about 0900, 14 May, an 8-in. manila line, with grapnel attached, was made fast to the pontoons, and this one line was all that maintained the integrity of the array until the shot, some 4 hours later.

A second stern gate casualty occurred on 14 May. At 1013 while launching LCM's, a heavy sea lifted the stern gate of the USS Comstock (LSD-19) to within 8 ft of closing and then dropped away, parting both port and starboard wire preventers and the port 1-in. easing-out wire. While attempting to raise the gate, the $\frac{5}{8}$-in. endless-wire relieving tackle and starboard easing-out wire parted. The gate thereafter trailed astern from the hinges until the return to

San Diego. The Comstock is likewise to be commended for performing her assigned duties well under most adverse sea conditions.

1.6.7 Test Execution, 14 May 1955

After all personnel were cleared of the array and accounted for, when all ships were in their assigned stations with respect to the YC barge, the Air Photographic Element reported on station, and when the radiological survey aircraft were on station, the first deep underwater nuclear detonation in history occurred at 1959:59.89 GMT, at 126°16′ west longitude and 28°44′ north latitude, on 14 May 1955.

1.6.8 Early Results and Clean-up Operations

Concurrent with arrival of the shock wave, SQUAW-12 collapsed, the last remaining chains parted, and the target sank. YAG's 39 and 40, having previously deployed to downwind stations, were to have conducted radiological surveys of the contaminated water area. YAG-39, however, suffered shock damage which caused temporary disability to her boilers and rendered her incapable of completing her mission. Accompanied by the Molala as escort, YAG-39 departed the area on 15 May and returned to San Francisco. YAG-40, although temporarily incapacitated on arrival of the shock, effected quick repairs and completed several runs through the contaminated area before being released on 17 May to proceed to port.

The C-54 photo aircraft of TE 7.3.5.2, being primarily concerned with the time interval of H−2 sec to H+30 sec, successfully accomplished their mission. The AD-5N survey aircraft, commencing the first upwind pass at H+11 min, made water-sample-collector drops and subsequent radiological surveys of the area as planned. The helicopter Visual and Radiological Survey Mission, although delayed 1 hr in waiting for area Rad-Safe information, was on station at H+75 min.

The remainder of 14 May was consumed in conducting radiological surveys, taking adrift pontoons in tow, and getting personnel back on board their respective YFNB stations. The array course was changed to the northeast in an effort to clear the contaminated area and to make way toward San Diego. Efforts to bring SQUAW-13 up were unsuccessful, indications being that the air was having no effect on blowing the ballast tanks. Gauge readings from YFNB-13, however, showed the pressure hull to be dry.

On 15 May the remainder of the array was disassembled. During the tow-wire and buoy retrieving phase, heavy swells caused the starboard bow ramp-hoisting wire on LST-975 to part. The port ramp-hoisting wire parted shortly thereafter when a strain was put on this wire while attempting to rerig the starboard wire. The bow ramp thereupon fell to the extreme down position and broke off. LST-975 continued to retrieve the tow-wire, however, and completed the task, taking on board some 19,000 ft of wire and 94 buoys in 9 hr, a feat considered noteworthy even under ideal conditions.

Upon completion of the array disassembly, the tows were detached to proceed to West Coast ports. YFNB-SQUAW-29 and YFNB-12 proceeded to San Diego at about 6 knots, and YFNB-13, with SQUAW-13 supported by only one pontoon, eased toward White Cove, Santa Catalina Island, at about 1 to 2 knots, where it was planned to salvage the SQUAW for post-shot analysis.

Effort was thereupon concentrated on tracking the contaminated water area and recovering instruments which were still suspended from flotation buoys. The destroyers were secured from their perimeter patrol and commenced a search to the south. Several valuable pieces of scientific equipment were recovered, and the area was cleaned of floating debris by gunfire.

On 17 May the pontoon supporting SQUAW-13 carried away, and the 2-in. wire to the bow of the SQUAW parted. Sonar was employed and indicated that the target was still suspended by the instrument bundle, and the tow continued toward White Cove.

On 18 May the remaining Navy ships departed the shot area, leaving the Scripps Institution of Oceanography ships to continue to monitor and track the contaminated water. The Scripps ships remained in the area until 24 May, at which time they too returned to San Diego.

1.6.9 Loss of SQUAW-13, 21 MAY 1955

On 21 May at about latitude 32°00'N, longitude 121°00'W, SQUAW-13 broke loose from the instrument bundle and sank.

All units were released from operational control of CTG 7.3 by 28 May, at which time the task organization was dissolved.

1.7 EARLY REACTIONS FROM OPERATION

1. Scientific participation: Sufficient data were obtained to meet the requirements of the test.

2. Radiological Safety: The radiological program as administered by NRDL under Project 0.17 was executed without incident. There were no reports of personnel being excessively contaminated. No aircraft were contaminated. All but two ships were assigned radiological clearances.

3. Aerology: During the Operation the Task Group Forecasting Team was embarked in the USS Mount McKinley (AGC-7), the task group flagship, and was receiving data from other afloat units, the Task Group Weather Central at NAS, North Island, and the Hydrographic Survey Element which was composed of three P4Y-2 aircraft. With the data from these various sources the Forecasting Team was able to evaluate and disseminate weather forecasts.

In the choice of site, weather was only one consideration. It was realized that climatological data were very scarce, but this was a direct consequence of the necessity for having a site off the air-traffic and shipping lanes, and thus out of the area of reliable data. From a weather standpoint alone, other areas were considered more favorable, but other considerations precluded these choices. From a forecasting standpoint, data were too scarce for wind forecasting with the accuracy required.

4. Communications: Task group communications were basically carried out as directed in CTG 7.3 Operation Order 1-55. The timing and firing systems and voice-time broadcast system as installed and operated by Edgerton, Germeshausen and Grier, Inc. (EG&G) personnel functioned efficiently, and only one project claimed nonreceipt of a −30-sec time signal. This failure may be attributed either to failure of the signal or to failure of the project equipment to function. The Motorola voice radio transceiver equipment proved most satisfactory.

5. Security: There were no violations which resulted in breaches of security sufficiently grave to warrant a formal investigation.

1.8 ORGANIZATION IN THE OPERATIONAL AND POSTOPERATIONAL PHASES

On 5 April 1955 the headquarters of CTG 7.3 was temporarily relocated from the U. S. Naval Gun Factory, Washington, D. C., to the headquarters, Special Projects Unit (SPU), at the U. S. Navy Electronics Laboratory, San Diego, to provide the Commander and his staff the better physical location in the staging area during that period prior to the final underway period of the operational phase, 5 May to 20 May 1955.

The division of responsibility between Headquarters, AFSWP, and this command during the preoperational phase as outlined by the Chief, AFSWP, was continued.

On 1 April 1955 the administration of the technical programs listed in the Experimental Plan for Operation Wigwam[5] was assumed by CTG 7.3 as a function of Task Unit 7.3.1, the Scientific Unit, under the Scientific Director, Dr. A. B. Focke. This Task Unit was activated on the same date in accordance with CTG 7.3 Operation Plan 1-55.

The responsibility for the administration, discipline, internal organization, and unit training of the participating naval forces and forces of other military departments was retained by their respective administrative commanders. CTG 7.3 administered the operational phase in much the same manner as in other overseas tests.

On 27 May 1955 CTG 7.3 relocated the staff headquarters at the U. S. Naval Gun Factory, Washington, D. C.

The operational phase was terminated on 28 May 1955, and the postoperational phase again reverted to the Field Projects Division, as a headquarters function.

1.9 COMPLETION OF OPERATION WIGWAM

On 28 May 1955 the postoperational phase became a Field Projects Division responsibility. Interim reports were required before scientific personnel were released from TG 7.3 control. These reports were prepared for direct photographic reproduction by the SPU section entitled "Office of the Scientific Director." Responsibility for final reports production was assigned to an officer who eventually was assigned to the Weapons Test Division, Headquarters, AFSWP, and a group of yeomen of this "office" under the Scientific Director. Preparation, review, and publication of these reports were controlled by this office and were completed.

Chapter 2

SUMMARY OF EXPERIMENTAL PROGRAMS

The arrangement of targets and scientific instrumentation locations is shown at the bottom of Fig. 1.1 and in Table 2.1.

TABLE 2.1 — BEST ESTIMATES OF RADIAL DISTANCES TO TOP OR SURFACE POSITIONS

Station	Distance, ft
YC-473	0
Ball-crusher string 1	1,410
Ball-crusher string 2	1,770
M-boat O_1	2,140
MPT-1*	2,755
Ball-crusher string 3	3,200
M-boat A_2	3,390
M-boat O_2	3,640
SQUAW-12	5,370
YFNB-12 MPT	5,440
Center	5,540
NEL string	5,570
NOL string	5,620
SQUAW-13	7,360
YFNB-13 MPT	7,860
Center	7,960
NEL string	8,000
NOL string	8,030
SQUAW-29	10,200
YFNB-29 MPT	10,840
Center	10,920
NEL string	10,960
NOL string	11,010

*MPT = NOL mechanical pressure-time gauge.

2.1 PROGRAM I

The objective of Program I was to measure the transient effects on the underwater free field in the vicinity of the detonation. The effects to be measured included:

1. Pressure-time history of the underwater shock wave at horizontal ranges from 0 to approximately 30,000 ft and at depths from the surface to approximately 1000 ft.

2. Peak pressures as a backup to the pressure-time measurements.

3. The maximum size and migration of the bubble.

4. The disturbance of the air-water interface caused by the shock wave and bubble.

5. Underwater light intensity as a function of time.

The underwater pressure-time field resulting from this explosion was well instrumented in the range from 500 to 11,000 ft from the weapon and appears to have been similar in most respects, at ranges greater than 1000 ft, to the pressure-time field to be expected from the detonation of 46,000,000 lb of TNT (Fig. 2.1). These results are in excellent agreement with the theoretical predictions received shortly before the operation.

Pressure-time measurements were obtained as follows:

1. By Project* 1.2 at six positions from approximately 2700 ft from Surface Zero out to approximately 10,600 ft. The pressures measured as a function of range were similar to those predicted from the detonation of 46×10^6 lb of TNT. Refraction of the transmitted shock wave was noticeable and was roughly as predicted by acoustic theory. The period of the first bubble pulse as taken from the pressure-time records was approximately 2.86 sec, which is in good agreement with that predicted from the detonation of 52×10^6 lb of TNT.

2. By Project 1.2.1 by telemetering and magnetic tape recording in place at Surface Zero. Measurements were made vertically above the weapon from 800 to 1975 ft.

3. By Project 1.3 from one location at each of the three YFNB instrument barges. Since the locations of the gauge strings of this project were at ranges comparable to several of those of Project 1.2, but of different gauge types, a comparison of the peak-pressure data obtained is of interest:

YFNB	Project 1.2, psi	Project 1.3, psi
12	860	850
13	600	609
29	440	430 (at 1000-ft depth)

Period of the first bubble pulse was measured as 2.85 sec.

No data were obtained at the two stations planned for direct measurements of bubble size and migration, nor were any data obtained in the attempt to measure the underwater light as a function of time.

Excellent photographic documentation of the disturbance to the air-water interface was obtained by Program VI and provided to Project 1.5 for analysis and evaluation.

Bottom-reflected shock wave: Local valleys and hills in the sea floor caused focusing and defocusing of the bottom-reflected wave. In at least one area, 15,000 ft from Surface Zero, the water was strongly whitened, indicating pressures in the neighborhood of 500 psi, which is about that expected at 10,000 ft and enough to cause collapse of light-hulled submarines. At other places, such as some of the gauge positions, the bottom-reflected shock appeared to be missing completely. At the Mount McKinley the effect of the bottom-reflected shock was several times as intense as that of the direct wave (5 miles). This difference was the combined result of at least three factors: (1) the direct shock was markedly weakened by the effects of refraction, (2) the reflected shock struck the ship at a much larger angle of approach, and (3) the strength of the reflected shock may have been modified by the contour of the bottom.

Spray dome: The initial spray dome caused by the arrival of the primary shock wave reached a maximum diameter of 15,000 ft and a maximum height of 147 ft. A second dome formed and was accomplished by individual spikes which reached a height of 800 ft at about 10 sec.

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*Project results are given in greater detail in the next chapter.

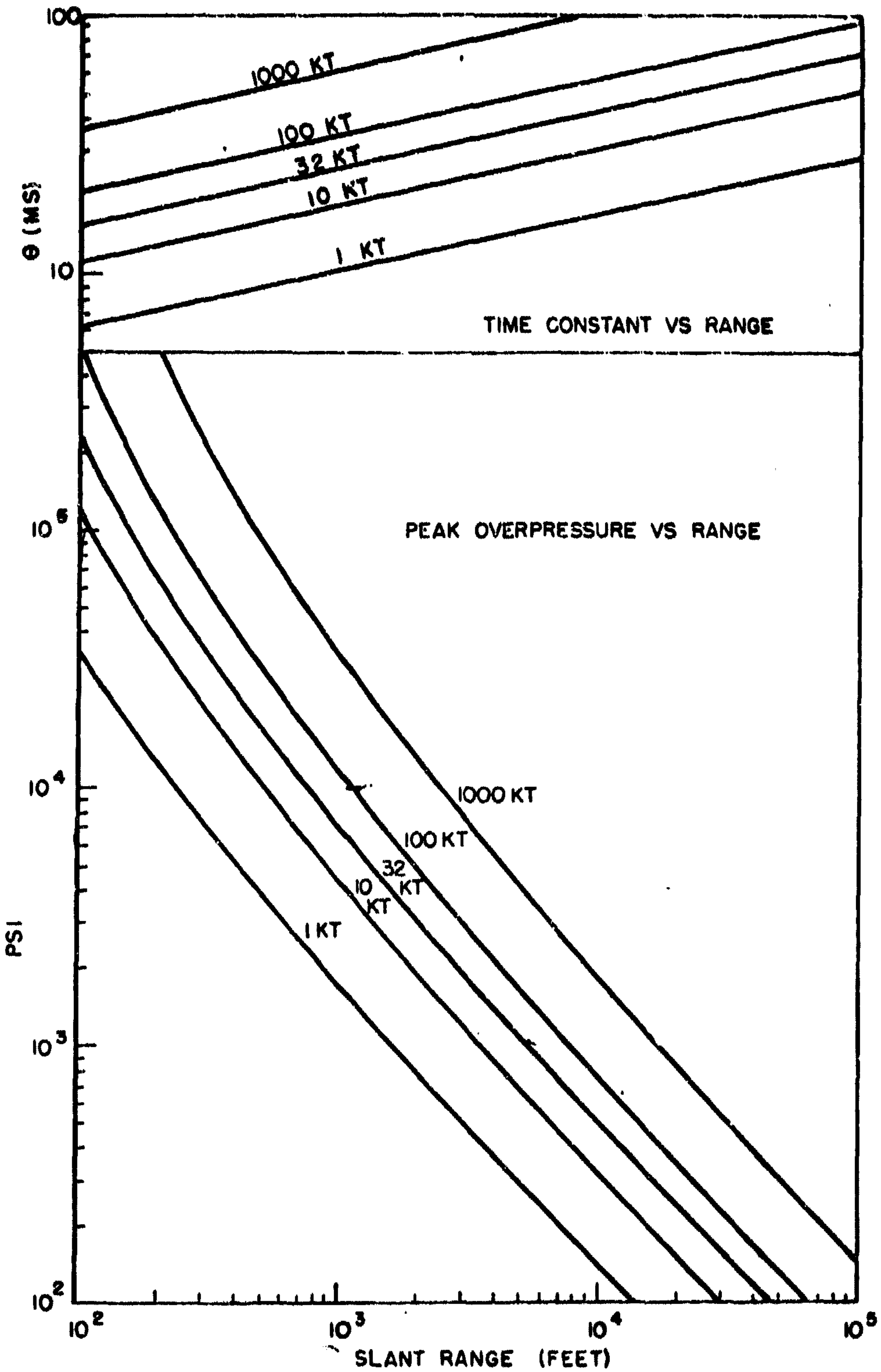

Fig. 2.1—Time constant vs range and peak overpressure vs range.

Plume formation: Two well-defined plume formations occurred, the first having a diameter of 3100 ft and reaching a maximum height of 1410 ft 19 sec after the detonation. The second reached a height of 770 ft 38 sec after the detonation.

Base surge: The outfall and descent of the material in the several plumes resulted in a well-defined base surge about 640 ft in height and extending outward about 4800 ft radially.

Surface waves: The collapse of the water crater formed surface waves that were about 2.5 times the height predicted. A well-defined breaking surface wave was first observed coming out of the base surge. This quickly became stable.

The YFNB-12, at a range of 5500 ft, rose and fell a distance of 37 ft, resulting in a product of range-times-height of 210,000. The maximum product predicted was 80,000. These waves were completely undetected at the task force elements at a range of 5 miles except that they showed up beautifully on one surface-search radar which was temporarily out of adjustment. It had been knocked out of service by the shock wave and, on being returned to service, the gain was set high so that strong sea return cluttered the scope face. The explosion surface waves modulated the sea return and were clearly visible until the radar operator returned the gain to

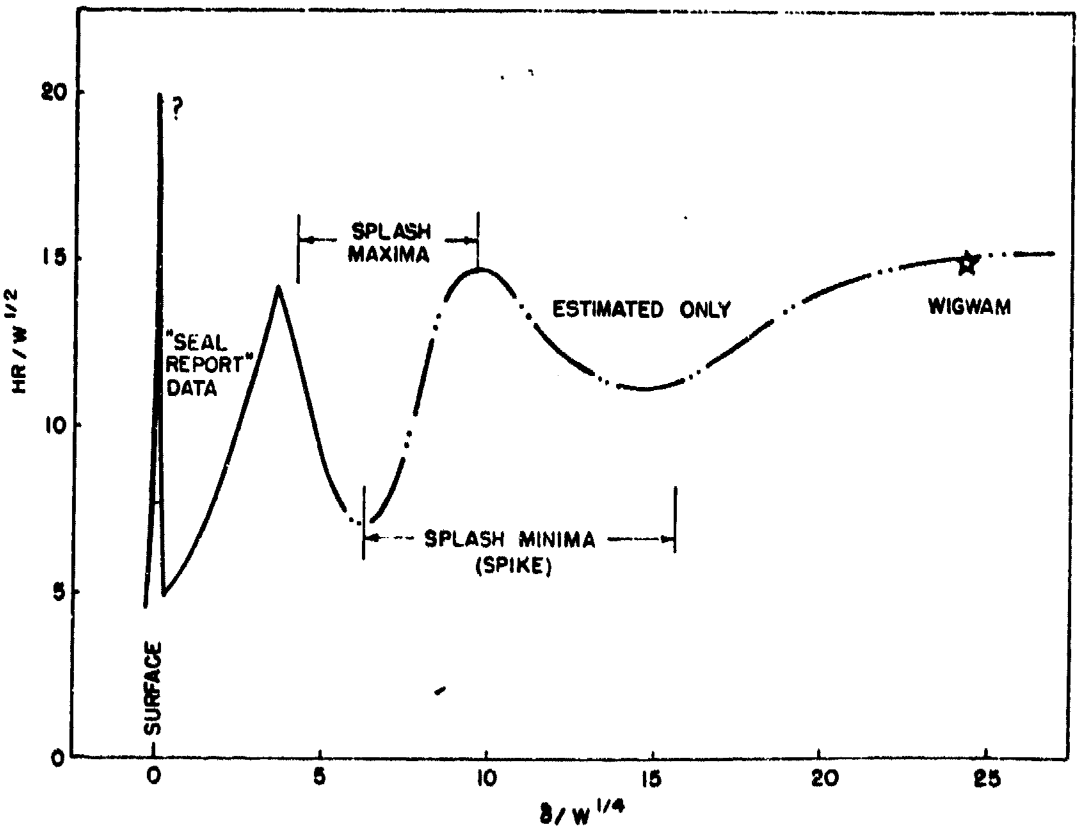

Fig. 2.2—Variation of wave heights with depth of detonation.

normal and quenched the sea return. About 15 waves were visible with wavelengths ranging from 5000 down to 1000 ft. The maximum energy appeared in the 1800-ft region. These waves could have serious implications in the case of detonation of thermonuclear weapons on or under the surface of deep water (Fig. 2.2).

The sounds were very noticeable through the hulls of surface ships at considerable ranges. A Greek ship just off the Golden Gate radioed the Coast Guard at San Francisco, asking if that city had just been hit by a severe earthquake. They had been badly shaken but were undamaged and would render assistance if needed: The time was 1312 PDT on 14 May.

The seismic shock was easily detected all over the world, and the U. S. Coast and Geodetic Survey (USCGS) reported an earthquake at 20:00.00Z on 14 May with epicenter at 29°N and 126½°W. The USCGS indicated that the time was accurate! Professor Beyerly, University of California, Berkeley, stated that either the time was in error by 4 sec (shot late) or the position was in error by 15 miles radius from Berkeley (greater) on the basis of the records he obtained alone.

The position of the shot was determined by the task group to be 28°44'N and 126°16'W with a probable error of 1' arc. This agrees excellently with Professor Beyerly's estimate. The sofar equipment at Point Sur, Calif., received a beautiful echo from the Hawaiian Islands. The Kaneohe sofar station in Hawaii got fine echoes from the California coast and also from the Gulf of Alaska.

2.2 PROGRAM II

The objectives of this program were both radiological and oceanographic in scope and encompassed the following efforts:

1. Collection of radioactive water samples from the surface and at depth.
2. Radiochemical analyses of these samples.
3. Determination of the radiological hazard to personnel aboard ships following an underwater nuclear detonation.
4. Investigation of the distribution of marine organisms in the area, their postshot contamination, and the probable effect of underwater nuclear detonations on marine organisms in general.
5. Determination of the nature of the water circulation induced by the event and its effect on the early distribution of fission products.
6. Tracking the dispersal of the fission products after the local circulation had ceased.
7. Measurement of the intensity and distribution of air-borne fall-out.
8. Assistance in selection of the test site on the basis of its oceanographic characteristics.
9. Prediction, from on-site measurements of currents, of the subsurface configuration of the array at the time of the detonation.
10. Supporting the task group in such matters as (1) the design and operation of a centralized plot exercising coordination control of aircraft and ship movements as required for aerial and surface radiological surveys and sample collections and (2) the placement of deep-moored skiffs to be used as postshot geographical reference points from which to follow the movement of water-borne activity.

Current velocities were of the magnitude and direction predicted for the area in which the test was held and prevented movement of water-borne activity onto land masses or into fishing areas before decay was sufficient to remove all hazards.

The bathymetry of the area showed the ocean bottom to be rather flat, with a depth usually greater than 2400 fathoms, but with a 6000-ft mountain about 5 miles south of the shot point. The minimum depth encountered was about 1700 fathoms, and the maximum was 2600 fathoms. Bottom material was red clay.

The fall-out and contamination resulting from this shot presented an ephemeral problem only. The major explosion plumes, which rose to a height of about 1400 ft and spread to a similar radius, were heavily contaminated, but the contamination was present in a very large mass of water and for the most part returned to the ocean surface promptly (within 1 min).

One deep and four surface air-dropped samplers were recovered after the detonation. All deep-towed samplers were set to operate at activity levels of 90 r/hr or greater and did not trip due to the low levels encountered. The early surface samples held about 4.2×10^{-13} parts of the bomb per liter. Samples taken from a depth of 130 meters at H+16 hr held approximately the same, 7 to 8×10^{-13} parts of the bomb per liter. Results on these and similar samples show a capture/fission ratio of 0.27 based on Np^{239} and total beta decay. Gross decay curves agree with a capture/fission ratio of 0.30. Gross activity for the period of measurement H+4 hr to D+6 days appears to have been proportional to $T^{-1.6}$.

Two converted Liberty ships, the YAG-39 and YAG-40, transited the radioactive area after the detonation. However, all transits were not completed as planned owing to shock damage to YAG-39 which immobilized her for about 4 hr. At H+17 min at a distance of 5 miles, YAG-39 received a fall-out reading of 400 r/hr. An effective washdown system reduced this level, under the washdown, to a maximum reading of 150 mr/hr. Had this ship remained immobilized and lacked the personnel protection offered by its shielded control room, the fall-out received might have been casualty producing.

The feasibility of delineating patches of contaminated water of from 1 to 100 sq miles in area using fixed-wing carrier-based aircraft under shipboard CIC control, and of measuring radiation levels with the New York Operations Office type scintimeter equipment provided, was successfully demonstrated. The delineation was accurate for practical purposes within the range of 1 mr/hr to 50 r/hr, which was roughly the region of relevance to this test. It is felt that the techniques involved are valid for much larger ranges of radiation intensities. This

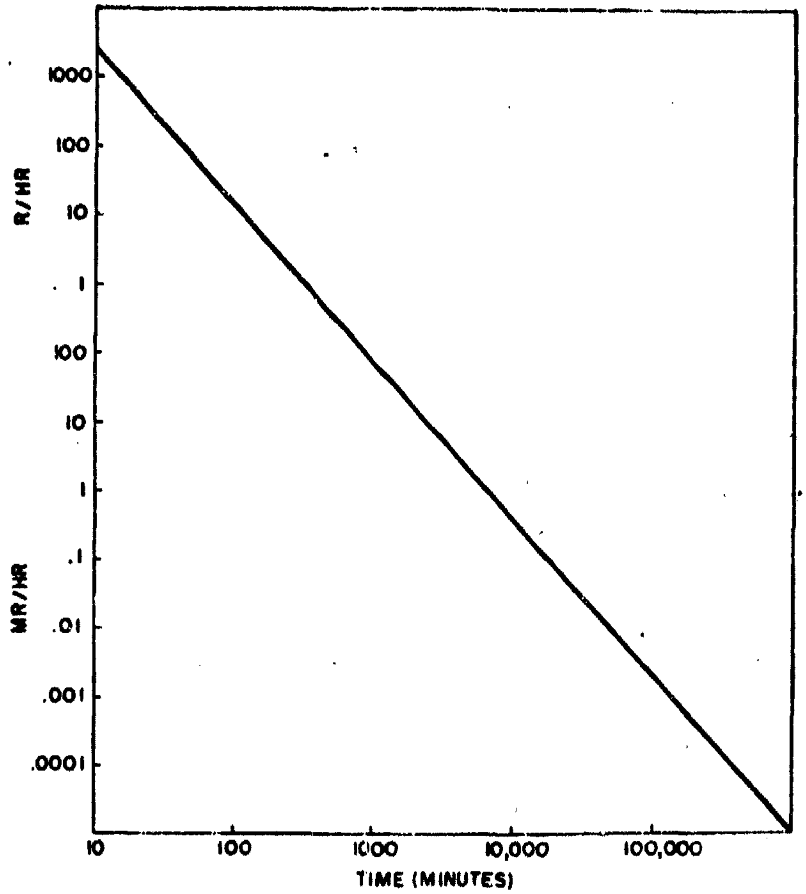

Fig. 2.3—Radiation level vs time (3 ft above water surface).

aerial survey technique will not only delineate areas of activity but will also yield information from which radiation contours can be plotted in sufficient detail to describe the tactical radiological situation. The synoptic nature of the data obtained is most convenient for this purpose.

The assessment of the radiological condition of the surface water was made by a variety of techniques, namely:

1. Aerial survey.
2. YAG-40 keel-deck measurements.
3. USQ-1 radiac telemetering buoys.

4. Helicopter survey.

5. Water sampling and probing from surface ships.

The radiological condition of the surface water in the first 13 min is not known by direct measurement. However, some of the DT-60 dosimeters placed aboard YC-473 were recovered. Four of these gave good readings and were closely grouped around 3600 r. Extrapolation of the aerial survey readings back to the probable time of initiation of dosage (H+14 sec, the time of venting) and integration of the dose rate also yield approximately 3600 r.

Standing crops of organisms in the test area at all trophic levels were low. There seemed to be some differential uptake by small marine organisms, and some showed a relatively high activity. Forage fish were very scarce. Continued attempts were made to determine the presence of commercial food fish by the long-line fishing technique before, during, and after the test. These involved 402 standard 6-hook baskets and yielded a total of only 15 sharks, 1 snake mackerel, and 1 opah, none of which are of commercial value.

Not one dead or stunned fish or mammal was observed as a result of the explosion from any task force ship, boat, or plane. This may be the result of two circumstances: first, the scarcity of fish in the area as described below and, second, the high probability that a shock wave having the slow decay of this one may be lethal to fish at extremely short range only.

The monitoring program of the California fish canneries produced no contaminated fish resulting from Wigwam. The tuna industry took the attitude that, if the Scripps Institution of Oceanography had determined the place for the detonation, there was no need to worry!

The water circulation induced by the detonation appeared to be extremely complex and difficult to analyze. A toroidal circulation persisted for at least $1\frac{1}{2}$ hr; however, thermal heating of the water and cooling by conduction do not seem to have played an important part in this circulation. Survey aircraft, equipped with infrared bolometers, made a continuous trace of surface water temperature as a function of time. No surface temperature variations greater than 1°C were discovered up to as late as H+18 min.

The area of surface activity moved to the southwest and west of the detonation point at a speed of approximately 0.2 knot as predicted. Areas involved were as follows:

Area, sq miles	Time	Max. radiation 3 ft above surface, mr/hr
5.5	0.5 hr	250,000
13.1	1.0 day	70
19	1.7 days	10
25	2.7 days	3
80	4.0 days	1
250	10.0 days	0.2
?	40.0 days	0.01

By D+10 days no area was found reading greater than 0.2 mr/hr 3 ft above the surface (Fig. 2.3). By D+40 no surface area was found reading greater than 10^{-2} mr/hr 3 ft above the surface. The surface areas at this time were ill defined and somewhat broken, with the center of the largest area approximately 120 miles west of the detonation point.

A number of lamellas of subsurface activity were encountered at depths of 250, 750, and 1250 ft during the 10 days following the explosion. The maximum activity encountered in these lamellas was 584 mr/hr at H+20 hr. No activity was found at any time below 1500 ft. Since the distribution of activity appears to have been about $\frac{1}{3}$ on the surface and $\frac{2}{3}$ subsurface, it would appear that no rapid precipitation of particulate matter occurred after its initial formation.

2.3 PROGRAM III

The objectives of this program were:

1. To measure and evaluate the loading by, and the response of three submerged targets to, the shock wave.

2. To determine the effects on the instrument barges caused by the shock wave.

3. To design, construct, and outfit the three targets and their associated instrumentation barges.

A description of the project activity within this program is to be found in the Experimental Plan,[8] and details as to the construction of the targets and instrument barges will be found in the respective project test reports in the next chapter. However, some comments regarding the philosophy underlying the design and construction of the targets and the method of connection of targets, salvage pontoons, and instrument barges may be appropriate in this chapter.

By the spring of 1953, study had resulted in several actual U. S. submarine target types being considered and rejected either on the basis of availability, handling complexity, nonuniformity, or cost. Inquiries had been made of ONI and CIA regarding foreign submarine sizes and capabilities which yielded the information included in the following paragraph.

Submarines of the USSR were constructed of high-alloy, high-strength steels equivalent to, or better than, our own Navy HTS grades. A USSR submarine structural design text was translated, and a comparison was made of Russian design practice with the known design of a heavy-hull U. S. Navy SS-285 class submarine. In general it was believed that the Russians preferred a somewhat smaller pressure-hull diameter for their submarines than the United States because this reduced the problems involved in transporting hull sections to advanced assembly yards. This information also revealed no known Russian submarine types with a pressure-hull diameter greater than about 15 ft. It was the consensus of the ONI personnel questioned that the modern USSR submarine had at least the deep diving capabilities of our own SS-563 class and was probably somewhat smaller in pressure-hull diameter. As a result of the above analysis of potential target capabilities, the SQUAW concept design and set of requirements was prepared for further development by BuShips. These were based on a $\frac{4}{5}$-scale target prototype of the SS-563 class but with interior framing.

This target offered several advantages over any full-scale submarine available. The cost was approximately equal to that of preparing and outfitting a heavy-hull fleet type submarine. It had the advantages of simplicity for model-scaling studies, structural uniformity for comparisons of performance between the same submarine types, and relative ease in handling and submerging. Also, advantage could be taken of the fact that it was "new construction" by providing certain construction features which would assure a resilient target for lethal-range analysis.

In the original planning for Wigwam, considerable thought had been given to the employment of surface-ship targets. Both combatant and merchant ship targets were to have been included in the array. It was originally planned to carry out surface-target damage investigations with sufficient range variations to establish both lethal bottom-attack and threshold equipment-shock-failure surface ranges. The reduction in scope of Wigwam limited surface-vessel participation to the three YFNB instrument barges.

A preliminary HE test program was initiated, with the NEL to study the response of the YFNB's to deep underwater atomic attack and the UERD to study the CL-108, CV-35 Chesapeake Bay Underbottom Explosion Tests of 1948 to ascertain the probable lethal-damage curves for combatant type surface ships. Both of these studies indicated that most surface targets would not sustain serious bottom damage at ranges greater than 4000 ft, and thus the location of the YFNB's would be such as to place them in the low-level shock-response range. They were instrumented to study their motions under this loading so that comparisons could be made between the velocity records so obtained and those obtained on other conventional explosive tests against surface ships.

By summer 1953 the size, weight, and shape of the SQUAW were developed to the extent that preliminary designs of the towing, submerging, and suspension arrangements could be studied, and it appeared that the arrangement to be used should have the following characteristics:

1. The suspension assembly and the target should be capable of being rigged as a unit in port prior to departure.

2. It should not interfere with the instrumentation bundle used in the measurement program.

3. It should withstand surge loads caused by swells with amplitudes up to 10 ft in the event of bomb-generated surface waves.

4. It should employ available components and be simple in concept.

5. It should be compatiable with the submergence scheme and easily handled.

The support assembly for each SQUAW consisted of eight 80-ton submarine salvage pontoons rigged four to a set with the SQUAW suspended by $2\frac{1}{2}$-in. die-lock chain. This multiple arrangement was conceived in order to reduce the maximum surge loading to that imposed by one 80-ton pontoon on each set of chain. This pontoon unit was streamed aft of the SQUAW while in surface tow. This arrangement assured that, while underway, the chains would not interfere with the air hose and instrument bundle which led forward from the nose of the SQUAW to its YFNB instrument barge. When the ballast tanks of the SQUAW were flooded, the target sank to a position directly beneath the pontoons in a double bifilar suspension.

The basic arrangement described above was subjected to numerous scaled and full-size tests by DTMB, UERD, Long Beach Naval Shipyard, and the task group, from the fall of 1953 through January 1955. The tests resulted in many minor changes but no major deviation from the basic concept of the pontoon-SQUAW-YFNB unit.

Movement of the three target units from San Diego to the test area involved about 290 hr of continuous working of the unit components in seas characterized by swells of not less than 5 ft and seas of not less than 3 ft. Of this total period there were perhaps 200 hr when the swells were greater than 6 ft with 4-ft seas. These conditions created two major problems with the units: those involving the instrument bundles and those involving the pontoons. The first proved the major hazard to the target instrumentation and the latter to target support, recovery, and continuity of the array.

The pontoon situation 170 hr after leaving port was as follows:

Unit	Situation
12	Two after pontoons adrift; both after chains parted
13	Forward port and after starboard chains parted; four pontoons holed
29	Forward port, after port, and starboard chains parted; two pontoons adrift; four pontoons holed

Such emergency repairs as were feasible considering sea and weather conditions were accomplished after arrival in the test area.

At the time of submergence, on D−1, SQUAW-29 was positioned as a surface target, SQUAW-13 was submerged suspended by one chain—one wire forward and one chain—one wire aft, SQUAW-12 was submerged suspended by two chains forward and two wires aft. SQUAW-12 broke from the after set of suspension wires prior to H-hour, and at H-hour was suspended by the forward chains only at an up-angle of 34° from horizontal. Both submerged targets were intact and dry prior to the detonation.

Each of the three targets was instrumented in an identical manner to measure the effects of shock wave loading on hull structure and internal components. Upon departure for the test practically all the instrumentation was ready and operable. The heavy seas mentioned above, however, caused continuous troubles due to chafing of the instrument-cable bundles. Numerous failures in the cable conditions occurred prior to shot time, the great majority of the failures reported being due to cable breaks rather than equipment failures. Also, many valuable data which were recorded in place were not recoverable owing to the loss of SQUAWS 12 and 13 or uninteresting owing to the use of SQUAW-29 as a surface target.

The immediate observable results of the test, as regards the submarine targets, showed SQUAW-12 sunk, SQUAW-13 intact with no flooding, and SQUAW-29 surfaced intact.

SQUAW-13, although intact, could not be surfaced and was subsequently lost during the 500-mile tow to the salvage site. For 300 miles this target was towed by the instrument cables alone.

Flooding of the main compartment of SQUAW-12 occurred within 3 sec after shock-wave arrival (condition recorded at 3-sec intervals). Flooding of the bow cone occurred at 27 sec, and final parting of the instrument cable occurred at 57 sec after shock-wave arrival. Thus the crushed hull sank nearly 400 ft in 1 min.

Interior photographic coverage of SQUAWS 12 and 13 was lost due to loss of the SQUAWS. Successful coverage was obtained in SQUAW-29, showing motions from the direct shock wave and from the bottom-reflected shock wave some 4 sec later. All motions were clearly visible. The reflected shock caused larger vertical motions than the direct shock.

For this test a critical criterion that has been suggested (Project 3.1) is that collapse will occur if the peak shock pressure to which the hull is subjected is given by the equation.

$$P_s = 1.08\,(P_c - P_0)\,(1 + e^{-T/18})$$

where P_c is the static collapse pressure, P_0 is the hydrostatic pressure, and T is the duration of the shock pulse in milliseconds.

A second criterion (UERD Report 16-56)[1] which may be less accurate but which is applicable to a wider range of conditions is that, if the excess impulse delivered by the shock to the submarine exceeds 2 psi-sec, collapse will result. The range determined by this method is not critically dependent upon the excess impulse value.

Figure 2.4 presents a variety of conditions for which this latter condition is satisfied.

These criteria indicate that a light-hulled fleet type submarine (650-ft static collapse) may be expected to receive lethal damage when operating at a depth of 250 ft if a 32-kt weapon is detonated 2000 ft deep at a range of less than 14,000 ft in deep water. Shock damage should be minor at ranges resulting in hull rupture.

The very minor damage received by the YFNB-12 (range 5500 ft) is in very good agreement with the prediction based on scale-model tests made by the NEL. These indicated that serious hull damage to the YFNB's should not occur at ranges greater than 4000 ft due to the shallow draft of these vessels. Surface ships at ranges in excess of 7000 ft should suffer only minor equipment damage which could be repaired at sea. This type of minor trouble may be expected out to ranges of several miles and should be the result of the shock wave reflected from the bottom rather than from the direct shock wave. It could become serious in shallower water. Under urgent conditions a surface vessel finding itself directly above a submarine could fire a nuclear depth charge off to a range of a mile downwind, thereby killing the submarine while sustaining minor damage itself.

2.4 PROGRAM IV

The objectives of this program were:

1. To procure, place, and arm the nuclear weapon at deep submergence.
2. To determine the weapon's performance by means of radiochemical and hydrodynamic analyses.
3. To evaluate the energy transfer from water to air as shown by air overpressure measurements above the surface of the water.

All the objectives of this program were met successfully, with the exception of those efforts relative to the measurements of air overpressures above the surface of the water. The lack of success here was due to the weather conditions prevailing in the test area which ultimately resulted in the loss of all the instrument-supporting balloons. Project personnel were able, however, to salvage some data at the Surface Zero and YFNB-12 locations by devising an emergency method of supporting their sensing elements just above the water surface at these two locations. The data obtained were in good agreement with the predicted air overpressures near the surface: 1.36 psi at YC-473 and 0.16 psi at YFNB-12 at a range of 5500 ft. The air shock duration was about 10 times that predicted by simple theory. These data confirm that

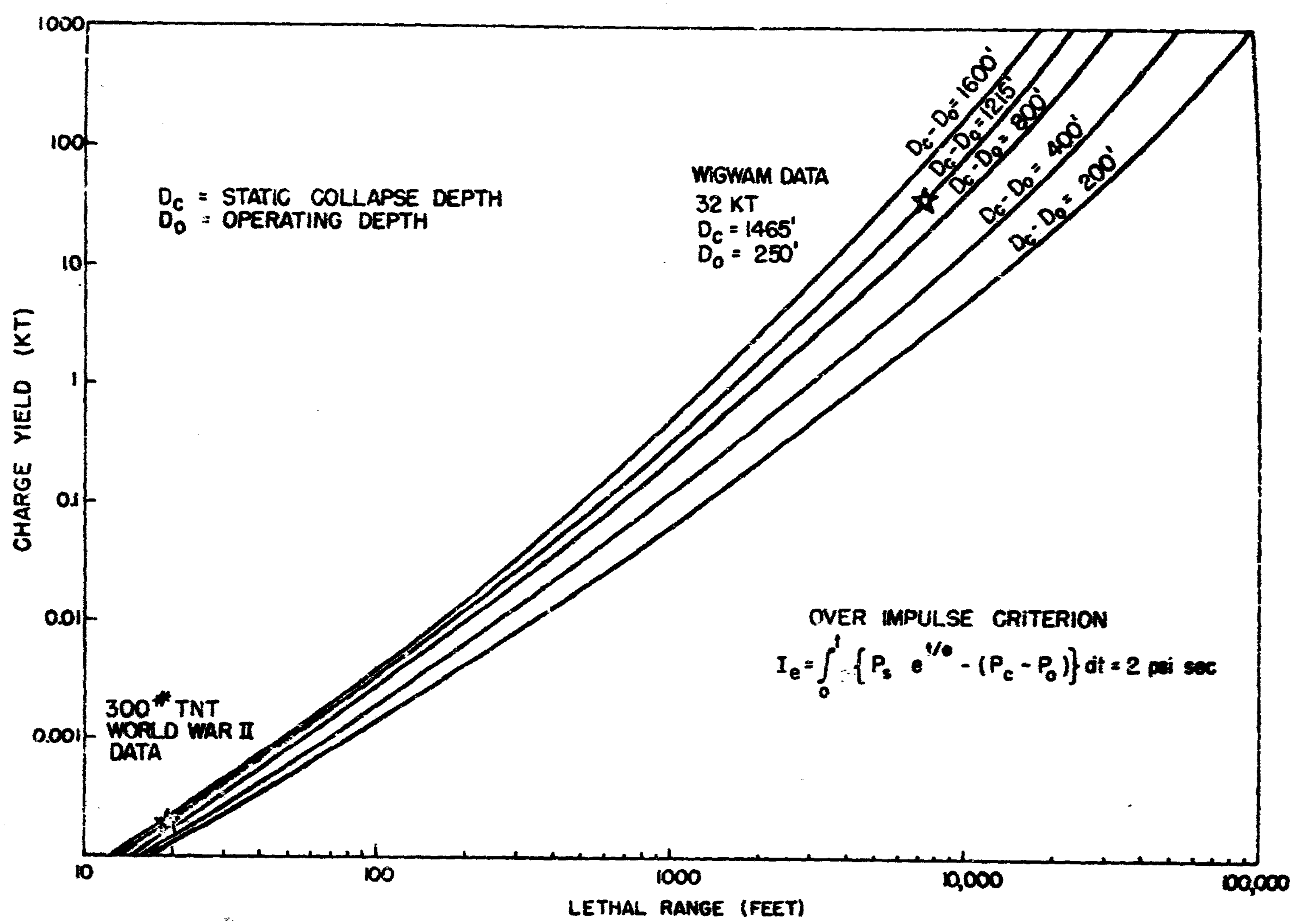

Fig. 2.4—Lethal range vs charge weight for various operating depths.

acoustic coupling can predict peak air pressures but not later pressures. On the basis that shock overpressures in air above 0.25 psi may be damaging to some aircraft, it may be seen that aircraft at horizontal ranges of more than 1 mile should be unhurt by the burst.

Radiochemical analyses by the Los Alamos Scientific Laboratory (LASL) and NRL indicate the most probable value for the energy yield of the weapon to be 32 kt, where the kt is defined as 10^{12} cal.

The close-in time of arrival of the shock wave was measured with good agreement between duplicate systems of electrical switches activated by shock pressures. Measurements were made at distances ranging from 14 to 2000 ft from the weapon at spaced intervals tied into the weapon support cable. Data obtained, time of arrival as a function of range, were as follows:

R, ft	Time of arrival, msec
14	0.04
29	0.24
65	2.2
316	39.3
1226	217
2000	364 (based on equipment microphones)

These results are in remarkably good agreement with theoretical predictions and indicate an energy release of 32 kt.

Details of the electrical modifications to the weapon, its incasement, support, etc., will be found in the pertinent project test report. During, and subsequent to, placement of the weapon at depth, continuous monitoring of the weathertight integrity of the case and maintenance of the proper voltage for firing the X-unit were performed by radio link between the YC-473 and the command ship. This monitoring indicated that normal conditions existed at the time of the detonation.

2.5 PROGRAM V

The objectives of this program were:

1. To build radio-controlled firing equipment and to outfit an appropriate control room on board the command ship.
2. To supply six standard timing signals and one zero-time fiducial signal to project locations as required.
3. To supply an arming signal, a firing signal, and three go-no-go weapon monitoring signals.
4. To supplement task group communications as requested.

The timing and firing systems employed are described in reports by Edgerton, Germeshausen and Grier, Inc.[6-8]

Seven switch-closure type radio time signals ranging from −45 min to zero time were provided to remotely controlled equipment. The −45- and −15-min signals were hand activated, and the remainder were initiated by the sequence timer which was activated by the −15-min signal.

The firing sequence was initiated by audio tones, controlled by the sequence timer, modulating r-f transmissions of 250-watt transmitters. These tones selected the "arm," "fire," and "stop" functions at the firing site.

The fiducial-marker signal was generated by the firing-switch closure at the firing site. This signal was transmitted directly to the projects concerned and was also used to activate a ½-second pulse generator aboard the command ship for postshot project use. The zero fiducial signal was reported to have been generated 29 ± 1 msec prior to actual detonation.

Approximately 200 switch-closure radio time signals were provided. Of this number, 135 were provided to central timing-distribution panels aboard the three YFNB's and the weapon

support barge. The remainder were provided to individual timing-signal receiver cans containing Vibrasponders, clocks, and three time outlets.

A crystal-controlled clock was maintained accurately calibrated to WWV time by frequent comparison and adjustment.

At shot time the timing and firing systems and voice-time broadcast operated successfully. The initial water-borne shock wave opened a locked-in relay in the ½-sec fiducial pulse transmitter, and these pulses ceased. The relay was manually reset after the last shock wave, and the pulses were transmitted for ½ hr thereafter.

The time of detonation was 12:59.59.888 Pacific Daylight Time on 14 May 1955. This time includes all corrections including that for transit of the WWV signal. This latter is estimated to be approximately 13 msec.

2.6 PROGRAM VI

This program had the following objectives:

1. The preparation of scripts for authorized nontechnical motion-picture photography.
2. The accomplishment of photography in accordance with approved scripts and in coordination with the test activities to be photographed.
3. The making of all negatives required to provide report coverage.
4. The provision of accident and general record coverage.
5. The provision of facilities and assistance to others in the processing of scientific photographic records.
6. The conduct of aerial photography as required.
7. The provision of timed technical photography.
8. Stowage, issuance, and accounting for film, and the cataloging and indexing of all exposed film.

All the objectives of this program were successfully met. Prior to the January 1955 handling trials, a training film was completed covering the methods and techniques involved in towing, submerging, and surfacing the SQUAW units. Postshot script films include a short report film suitable for eventual public release if required and the Task Group Commander's film report.[9,10]

Timed technical photography, both surface and aerial, as required for Program I, was successfully completed. Surface coverage from manned stations was obtained from stations on board the Curtiss and Mount McKinley and from unmanned stations on YFNB's 12, 13, and 29. Aerial coverage was obtained from three C-54 photographic aircraft located at ranges of 10,000, 15,000, and 20,000 ft from the detonation point and at altitudes of approximately 2500 ft.

Aerial mosaics showing the elements of the array from YC-473 to YFNB-29 were made utilizing one RB-50 photographic airplane. These mosaics were successful in establishing the surface configuration of the array both prior to and after the detonation.

2.7 RECOMMENDATIONS

1. Using scaled explosions and targets, studies should be made to determine safe and fatal ranges for various types of submarines and surface vessels.
2. Previous estimates of optimum warhead yields and explosion depths should be reevaluated in the light of the Wigwam results.
3. Scaled experiments should be performed to extend and improve the estimates of wave production by explosions. This may critically affect the use of thermonuclear weapons.
4. Marked reduction of the hull-splitting ranges for submarines may result from increased collapse depth and radical design concepts which should receive careful study.
5. Should additional tests of this nature become necessary, the area used appears excellent from the standpoints of international and fishery relations. If anticipated, the weather and sea conditions are not prohibitive.
6. It will probably be necessary to check safe ranges for delivery vessels and refraction effects by additional full-scale tests.

Chapter 3

SUMMARY OF SCIENTIFIC PROJECTS

PROJECT 0.02

TITLE: Target Response Studies Using High Explosives [NEL Research Report 637 (AFSWP-879), dated 29 December 1955, Secret-RD]

PROJECT OFFICER: C. T. Johnson

ORGANIZATION: U. S. Navy Electronics Laboratory, San Diego, Calif.

1. Objectives

a. Determine the lethal range from a 31-kt TNT charge for a model submarine of the order of $\frac{1}{50}$- to $\frac{1}{60}$-scale for end-on attack with the submarine model at 250 ft.

b. Determine similar lethal radii for the same model type at various depths of submergence to at least 1000 ft.

2. Results

a. The lethal range at 250-ft submergence for a 600-psi collapse strength, $\frac{1}{59}$-scale, idealized submarine model built of low-carbon steel was 92 ft from a $\frac{1}{61}$-scale charge. The lethal range at other depths was found to correlate well with a constant overimpulse of the incident shock wave, i.e., the area of the pressure-time curve above the static collapse strength of the target. Figure 3.1 presents a summary of the data obtained.

b. The horizontal range for incipient bottom damage to a $\frac{1}{30}$-scale model YFNB from a scaled charge at a depth of 2000 ft was found to be between 125 and 200 ft.

c. The measurements made on the YFNB models indicated that initial shock velocities of the YFNB's at the Wigwam test might reach 7 ft/sec and that bodily displacements up to 4 or 5 in. were likely with motions of 8 to 10 in. possible. (One measurement at the Wigwam test confirms the smaller values.)

3. Recommendations

a. Study the behavior of the SAE 1010 steel used in the submarine models at high rates of strain. It is believed that a full understanding of the delayed-yield effect exhibited by this material will make possible accurate extrapolation from model tests to full-scale results.

b. Conduct further experiments to determine the laws governing the response of surface targets to attack by shock waves of relatively long duration and at various angles of incidence.

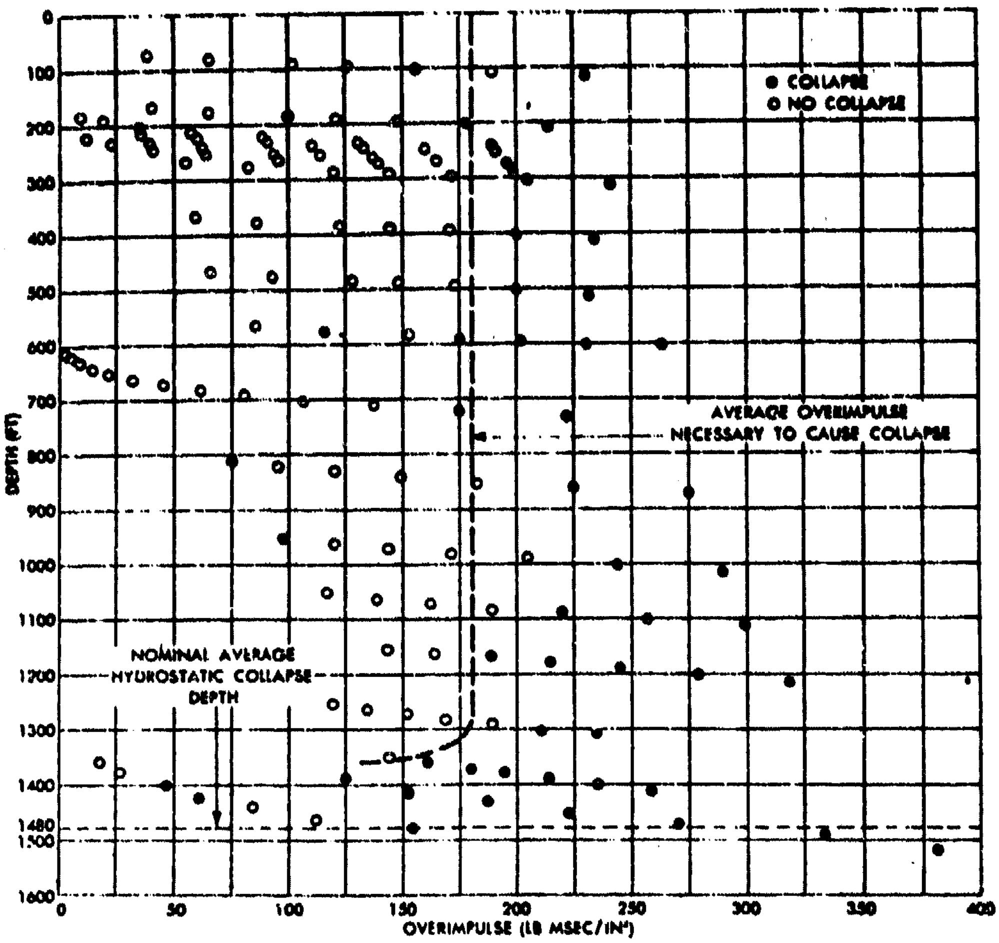

Fig. 3.1—Overimpulse required to crush submarine models at various depths.

PROJECT 0.03

TITLE: Project Wigwam Towing (DTMB Report C-669 dated December 1954, Secret)

PROJECT OFFICER: Emily A. Sykes

ORGANIZATION: David Taylor Model Basin, Washington 7, D. C.

1. Objectives

a. Evaluate the handling techniques and towing characteristics of the various Wigwam array components.

b. Determine the forces acting on the target pontoon support for a variety of sea and swell conditions.

c. Make a qualitative analysis of the wind effect on the complete array for winds up to 10 knots.

2. Results

Model tests were made on $\frac{1}{12}$-scale units of the Wigwam array. Physical size prevented towing more than two combined units. Data and computations were obtained showing graphi-

cally the towing resistance of various components, the effect of wind forces, and the cable configurations which may be expected.

3. Conclusions

Based on tests and computations it was concluded that the Wigwam array could be towed successfully by providing a drag force on the after end of the string. For a design speed of ½ knot, it was estimated that a stern drag of 2000 lb would be sufficient to ensure stability in sea states no worse than state 3.

PROJECT 0.06

TITLE: Project PAPOOSE [UERD Report 18-54 (AFSWP-256), Secret-RD]

PROJECT OFFICER: Dr. A. H. Keil

ORGANIZATION: Underwater Explosions Research Division (UERD), Norfolk Naval Shipyard, Norfolk, Va.

1. Objectives

Bracket the hull-splitting standoff, and provide target-response measurements for a realistic model of the SQUAW at approximately 1:5 scale.

2. Results

Four explosive tests were conducted against PAPOOSE models which were 1:5.33 replicas of the SQUAW targets. The shock-wave loading was produced by a tapered charge which was specially developed for this purpose. The shock wave from this PAPOOSE charge simulated the expected shock-wave loading for an atomic weapon attack against the prototype SQUAW. The following conclusions were drawn from the results obtained:

a. Range of Critical Hull Damage: For the particular Wigwam geometry the range from hull-splitting to light-moderate hull damage is extremely narrow, comprising not more than 10 and probably only 5 per cent standoff variation.

b. Pattern of Dynamic Response: Based on the response measurements made during the tests, a general picture of the dynamic response of a submarine to the end-on attack by an atomic explosion was derived.

c. Damage Pattern: The damage to the pressure hull consisted of lobe formation (dishing of the hull plating), especially in the vicinity of the tank tops. For more severe loading, stiffener deformation in the crown was superimposed (caving-in).

d. Damage Mechanism: Rupture of the pressure hull occurred as the result of a caving-in of the crown in the cylindrical section, which was a failure of the general instability type. This failure was triggered by early asymmetrical deformations associated with considerable plastic deformation leading to strains of 0.5 to 1 per cent in the hull plating.

e. Hull-splitting Standoff for SQUAW: The hull-splitting standoff for the SQUAWS at Operation Wigwam for a weapon yield of 32 kt TNT was derived as certainly more than 6000 ft and less than 7400 ft, probably 7000 ft.

f. Variation of Hull-splitting Standoff with Depth and Yield: Extrapolations could be made to show within limits the variation of lethal standoff with depth of submarine, as well as depth and yield of the weapon.

3. Recommendations

It is considered of extreme importance to conduct a thorough comparison of the PAPOOSE results with the results obtained from the SQUAWS during Operation Wigwam. Such a study should check the validity of scaling considerations and indicate possible modifications to present concepts. The PAPOOSE results, in terms of lethal standoff for different depths of the submarine and different depths and yields of the weapon, demonstrate the potentialities of tests

with realistic submarine models and tapered charges as a means of determining the response of submarines to atomic explosion. It is believed that this test technique can be used to considerable advantage for the following additional studies:

a. To appraise the effect of slight structural differences, as they exist between submarines of the same class, so as to derive kill probabilities.

b. To improve the design of submarines by incorporating in the models any recognized improvements as, for instance, increase in instability collapse pressure.

c. To obtain information on the hull-splitting standoffs for a variety of rather different submarine designs. This information, together with the above scaling study, should provide a good foundation for deriving general weapon effects conclusions from the Wigwam test against SQUAW.

d. To derive a valid and realistic concept of the damage mechanism for submarines under atomic depth-charge attack.

PROJECT 0.13

TITLE: Caribbean Area Study (Letter Report)

PROJECT OFFICER: Alyn Vine

ORGANIZATION: Woods Hole Oceanographic Institution (WHOI), Woods Hole, Mass.

1. Objective

Determine the suitability of the Caribbean area for an underwater nuclear test.

2. Results

The large values and variability of the currents found in the study area indicated that the contaminated water resulting from a submarine burst of a nuclear weapon would very probably wash foreign shores before decaying to a safe level.

3. Recommendation

The proposed test should be fired in some ocean area other than in the Caribbean.

PROJECT 0.17

TITLE: Radiological Safety for Operation Wigwam (Operation Wigwam, WT-1001, Confidential-RD, A. L. Baietti and A. L. Smith)

PROJECT OFFICER: A. L. Baietti

ORGANIZATION: U. S. Naval Radiological Defense Laboratory, San Francisco, Calif.

1. Objectives

Provide radiological safety support for Operation Wigwam. This support included:

a. Protection of personnel and equipment.
b. Effective training of personnel.
c. Evaluation of the effectiveness of Rad-Safe training and radiac equipment.

2. Results

The project personnel were trained and operated as a unified group with duties and responsibilities extending to all sections of the task group.

The dosage and contamination control problems encountered were of a minimal nature. The maximum individual dosage encountered was approximately 10 per cent of that allowed for the operation.

The value of extensive planning and of an integrated organization for radiological safety during field operations was demonstrated.

3. Recommendations

On the basis of the experience gained during the Operation, it is suggested that a continuing Rad-Safe organization would best serve the needs of Joint Task Force Seven. Such an organization could be maintained on a skeletal basis between field operations and could be expanded for each operation on the basis of specific requirements. Continuity in survey and dosimetry records could be maintained, and conditions favorable to the development of improved Rad-Safe procedures and equipment would be created.

PROJECT 0.31

TITLE: Photographic Recording of Ship-borne Radar Information (Operation Wigwam, WT-1038, Secret-RD, Ernest H. Boldrick and Vernon G. Heger)

PROJECT OFFICER: Ernest H. Boldrick

ORGANIZATION: Photographic Section, U. S. Navy Electronics Laboratory, San Diego, Calif.

1. Objectives

Record radar information that would provide data for the preparation of geographic plots of ship and airplane positions vs time by photographing:

a. The visual presentation on shipboard air- and surface-search radar repeaters.

b. The range and bearing meters on a specially constructed data panel which was connected to a fire-control-radar system.

2. Results

The storing of radar information that would provide data for the preparation of geographic plots of ship and airplane positions vs time was accomplished by photographing: (a) the visual information appearing on air- and surface-search radar repeaters aboard the USS Mount McKinley (AGC-7), the USS Ernest M. Small (DDR-838), and the USS McKean (DDR-784); and (b) the range and bearing output of the gunfire-control-radar systems as it appeared on specially constructed data panels aboard the Ernest M. Small and the McKean (Figs. 3.2 to 3.4).

Owing to operational difficulties the data panels yielded partial and intermittent data. The PPI radar recordings are considered satisfactory for positioning of ships and aircraft within the accuracy of the radars used.

Some of the photographic recordings clearly show surface disturbance and the resulting surface wave (Fig. 3.4).

3. Recommendations

The radar recording systems described appear adequate and desirable for operations that are conducted away from known landmarks or geographic features that can be used for triangulation purposes. Such systems may not be necessary when geographically fixed radars or tracking devices can be used.

PROJECT 1.1

TITLE: Predictions of Underwater Explosion Phenomena (Operation Wigwam, WT-1004, Secret-RD, H. G. Snay, J. F. Butler, and A. N. Gleyzal)

PROJECT OFFICER: C. J. Aronson

ORGANIZATION: Explosives Research Department, U. S. Naval Ordnance Laboratory, White Oak, Silver Spring, Md.

Fig. 3.2—Air-search presentation, sample frame.

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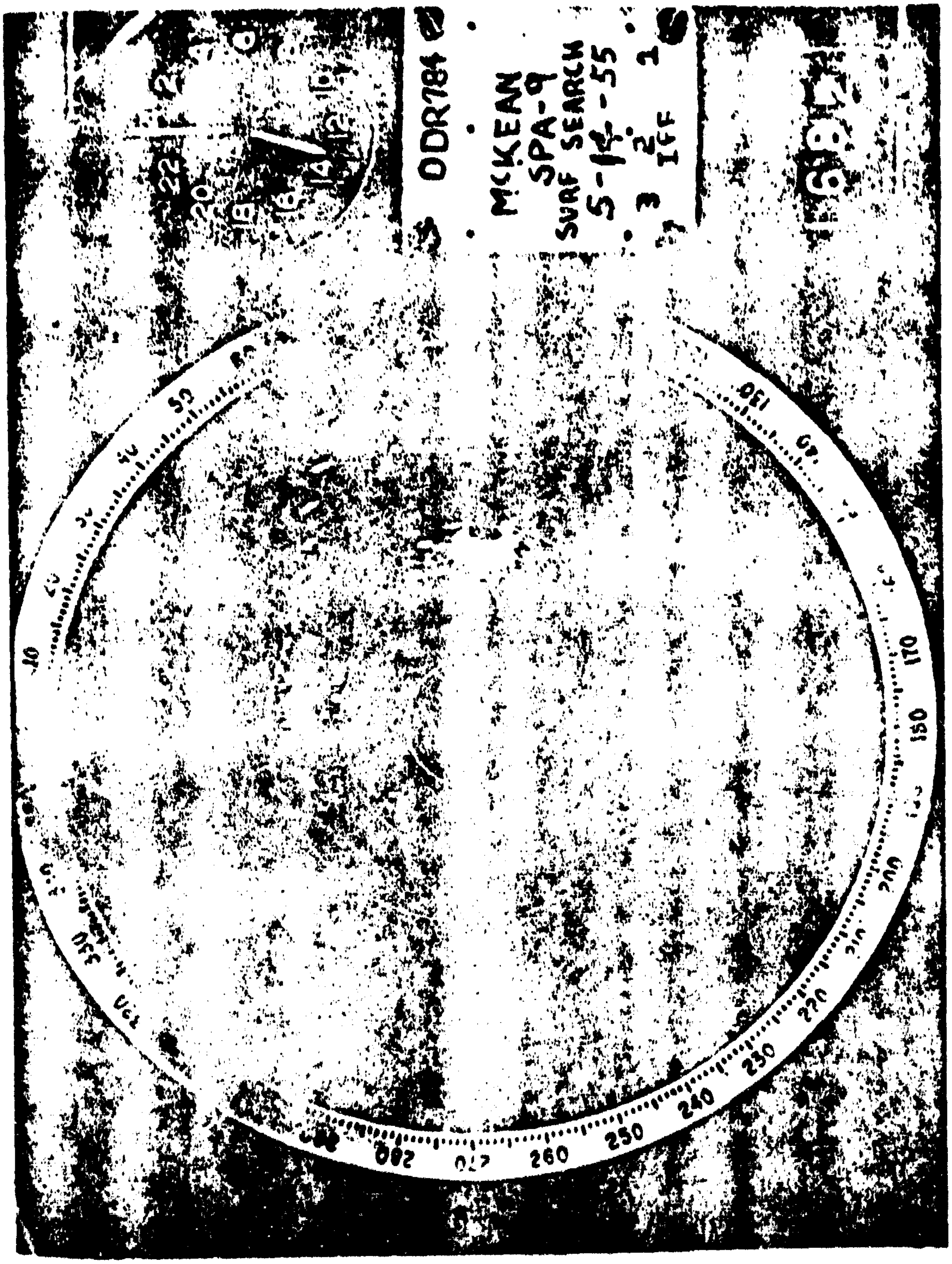

Fig. 3.3—Surface-search presentation, sample frame.

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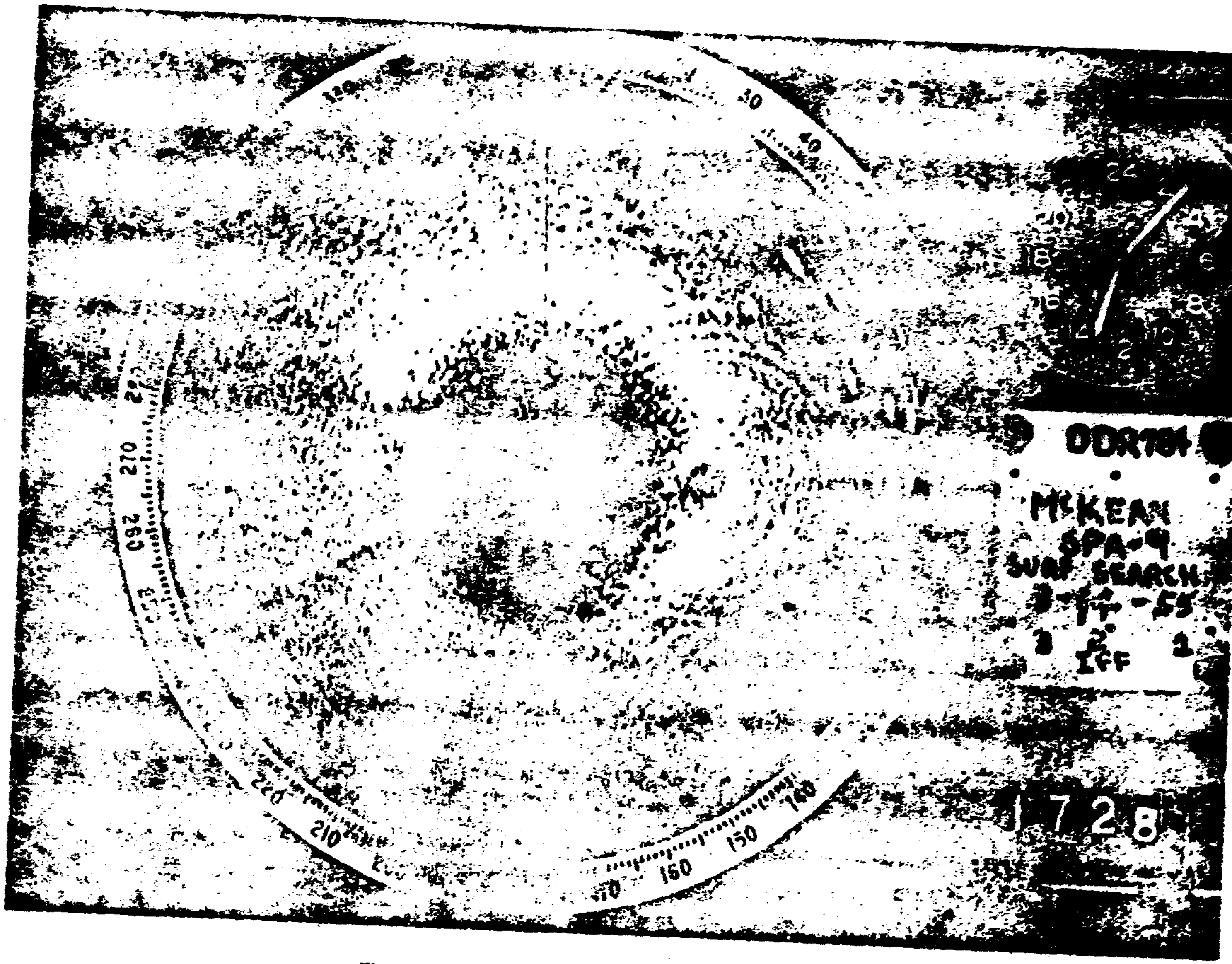

Fig. 3.4—Surface disturbance showing waves at + 7 min.

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1. Objective

Determine the principal underwater explosion phenomena from the explosion of an atomic device, having an energy yield of 30 kt, at a depth of 2000 ft in deep water, in order to:

a. Increase the knowledge of such phenomena.

b. Enable the proper location of the targets and instrumentation during the operation.

c. Further develop methods for predicting underwater explosion phenomena from other yields and firing geometries.

2. Results

A survey is given below of the various phases of calculations which led to the quantitative prediction of the important underwater explosion parameters for Operation Wigwam.

The Equation of State for Water: The analysis of the explosion phenomena requires a knowledge of the thermodynamic properties of water over an extremely wide pressure range, i.e., from infinity down to the low pressures of an acoustic wave. No equation of state is known which satisfactorily covers this range; therefore five separate pressure ranges were considered:

Region I. At extremely high pressures and temperatures the molecules of water are completely dissociated and ionized. The gas is ideal and monatomic if the small effects of radiation pressure and electrostatic forces are excluded.

Region II. For somewhat lower pressures and temperatures the medium is only partially dissociated and ionized. Laborious equilibrium calculations were made to determine the thermodynamic data in this region. The p-v-t relation necessary for this purpose was obtained from the detonation theory of high explosives, in particular hydrazine nitrate which forms water as its principal reaction product.

Region III. At still lower pressures and temperatures the water molecule remains intact. For this range, calculations using the Thomas-Fermi-Dirac theory were made.

Regions IV and V. For pressures from 725,000 psi down to acoustic values, direct experimental measurements, notably by Bridgman and by Carnevale and Litovitz, were used.

Shock-wave Phenomena: These calculations were also separated into several parts. For extremely high pressures the solution of the point blast problem of Taylor is applicable. For lower pressures the three partial differential equations of the spherical fluid motion were integrated. The method was not tractable below a shock pressure of about 450,000 psi (corresponding to a shock radius of 81 ft in Operation Wigwam). The calculations were extended to low pressures by means of the Snay-Matthias shock-wave theory. At very low pressures, asymptotic relations, similar to those first derived by Kirkwood and Bethe, were used.

Bubble Phenomena: The energy dissipation (i.e., conversion from mechanical into thermal energy) at the front of the intense shock wave from a point explosion produces the heat which vaporizes the water and forms a steam-filled cavity. This bubble pulsates in a manner similar to that observed for bubbles produced by high explosives. The analysis yielded the maximum bubble radius and the period of the first pulsation, as well as the total mass of water evaporated up to the moment of the first bubble maximum. The later bubble phenomena, including the rapid upward migration, can be calculated from data for high-explosive gas bubbles. This establishes an upper limit for the periods and for the migration of a steam bubble. The actual behavior of steam bubbles has been studied with model tests, using electric sparks as energy sources. The results of these tests were used to obtain information on the amount of condensation which occurred in Wigwam. It turned out that almost all the vapor must have been condensed before the bubble reached the surface and that the surface phenomena which had some resemblance to the "breakthrough" of a gas bubble were produced by the violent upwelling of the water which previously surrounded the bubble and which acquired the latter's upward momentum.

In summary, it was found that, in the region where pressures are less than 3000 psi, the calculated pressure-distance curve is similar to one from TNT having about 69 per cent as much energy (Fig. 3.5). In this same region the calculated shock-wave energy flux-distance curve is similar to one from TNT having about 82 per cent as much energy (Fig. 3.6). The

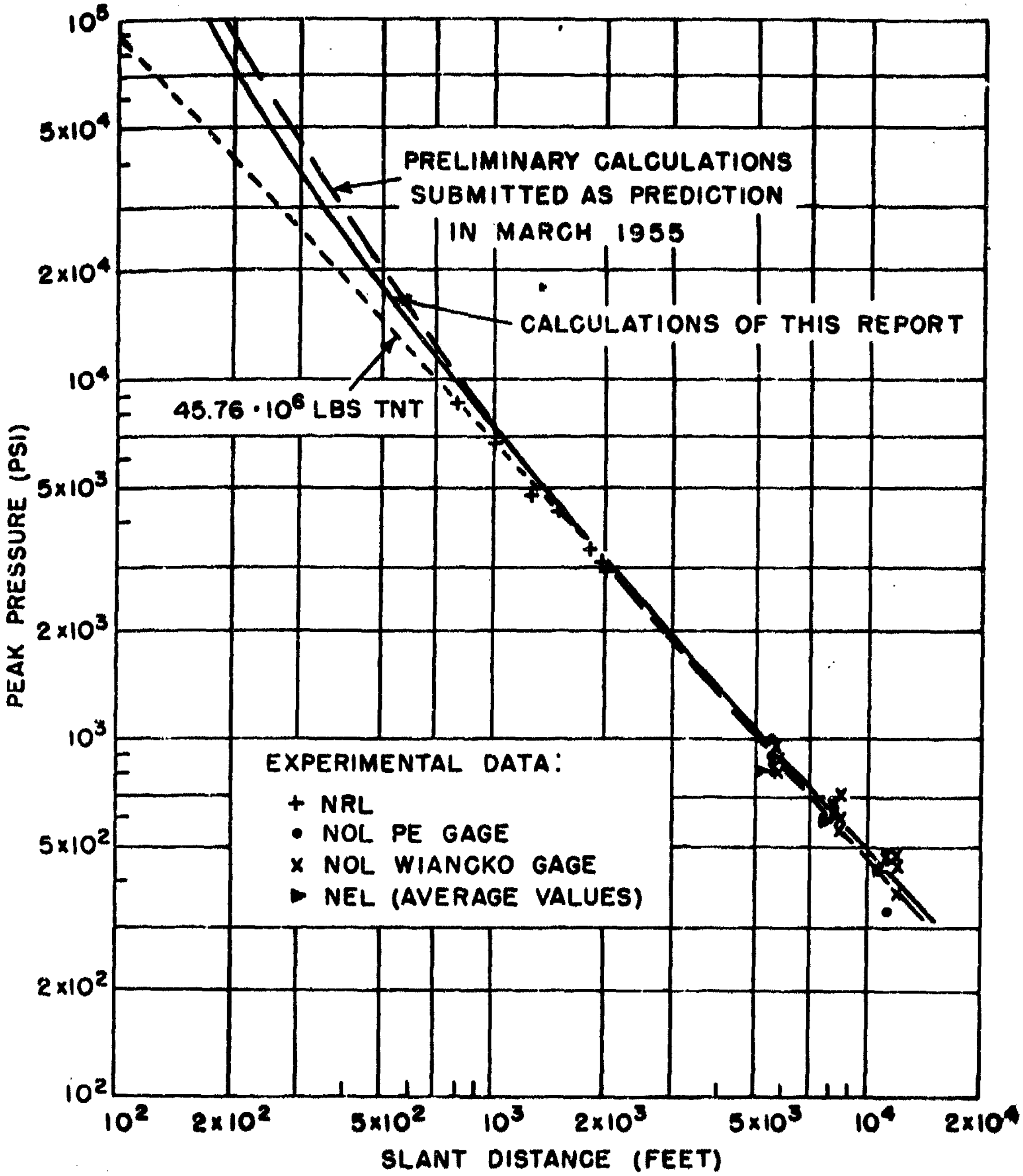

Fig. 3.5—Peak pressure vs slant distance.

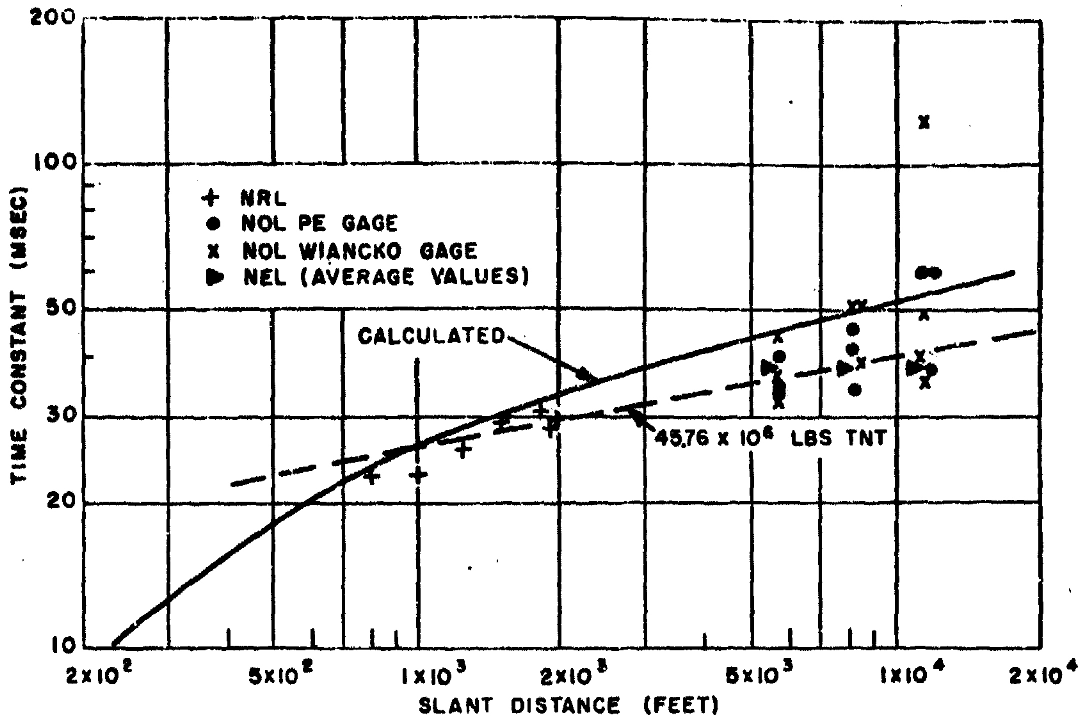

Fig. 3.6—Time constant vs slant distance.

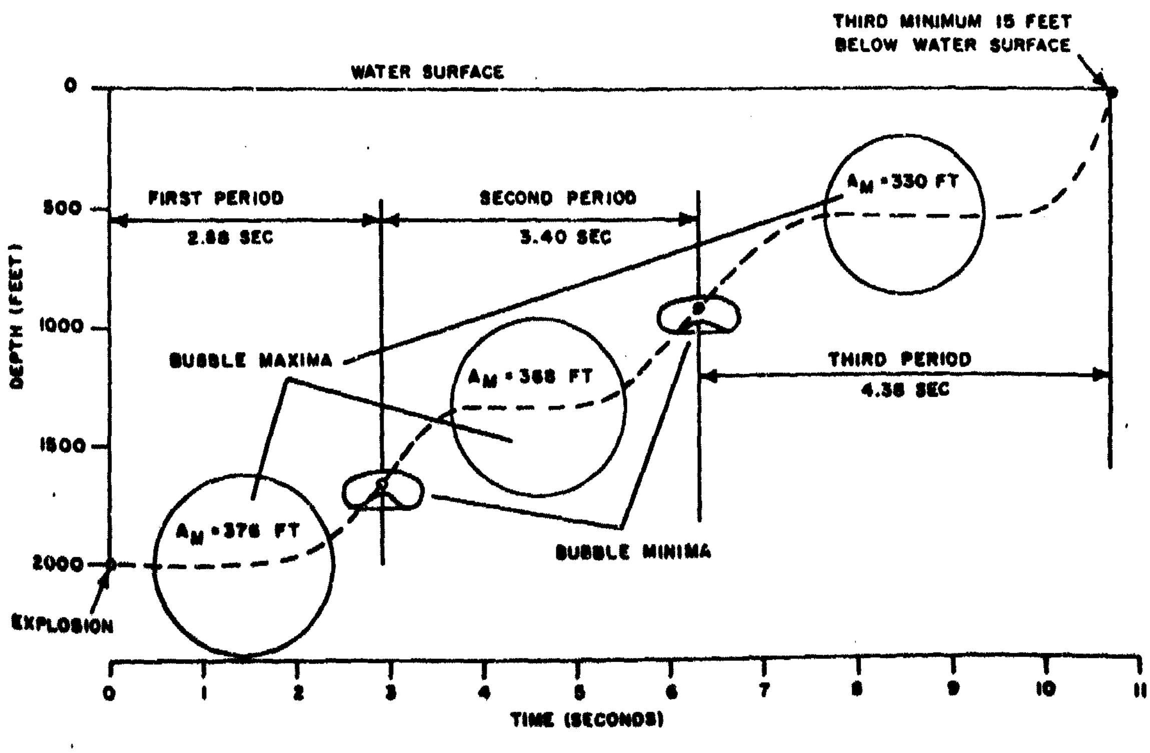

Fig. 3.7—Migration of a gas bubble.

maximum bubble radius was calculated to be 376 ft with a first bubble period of 2.88 sec (Fig. 3.7). This period corresponds to that from TNT having 81 per cent as much energy. The amount of water evaporated was calculated to occupy the volume of a sphere of 30 ft radius.

3. Recommendations

a. Equation of State: If other than a quasi-empirical equation of state for water is desired, considerable basic research will be required. A survey of government-sponsored theoretical research in physical chemistry is recommended to determine if all reasonable possibilities are being effectively exploited.

b. Shock Wave: It is recommended that theoretical work be continued toward improving the prediction of time constants and the determination of the variables influencing their values. Machine integration of the pressure data is recommended in order to have more accurate experimental data to compare against as yet untested shock-wave energy theory.

c. Bubble: It is recommended that quantitative efforts be made to unify the information of Project 1.5 with the theory of Project 1.1.

PROJECT 1.2

TITLE: Underwater Free Field Pressures to Just Beyond Target Locations (Operation Wigwam, WT-1005, Secret-RD, C. J. Aronson, J. P. Bampfield, E. A. Christian, E. J. Culling, V. F. Devost, F. J. Oliver, R. S. Price, J. P. Slifko, and M. A. Thiel)

PROJECT OFFICER: C. J. Aronson

ORGANIZATION: Explosives Research Department, U. S. Naval Ordnance Laboratory, White Oak, Silver Spring, Md.

1. Objective

Measure peak pressures and pressure vs time underwater in the region from about 1500 ft to about 12,000 ft from Surface Zero arising from the explosion of a 30-kt atomic bomb fired at a depth of 2000 ft in about 15,000 ft of water. Measurements were to be made from depths of 25 to 2000 ft, including the region where large scaled models of submarines were located as targets.

2. Results

The principal results of this experiment were:

a. The peak-pressure–distance curve for free water in the region measured was essentially as predicted by Project 1.1 and was similar to one which would have resulted from an explosion of TNT having a yield equivalent to $\frac{2}{3}$ the radiochemical yield of 32 kt (Fig. 3.8).

b. The best estimate of the first bubble period was 2.878 sec, from which was calculated a TNT yield equivalent to $\frac{3}{4}$ of the radiochemical yield. This result can be compared with the Project 1.1 prediction of 2.88 sec. The second and third bubble periods were 1.6 and 1.9 sec, respectively. Migration of the bubble to about time of the first minimum was 400 ft (Figs. 3.9 and 3.10).

c. The effect of the temperature structure in the water in refracting the shock wave was essentially as predicted—increasing the pressures and decreasing the duration of the shock wave.

d. Shock-wave energy flux and impulse varied with distance differently from TNT in a homogeneous medium when corrections were made to account for the time of integration. The differences are believed to have arisen from a basic difference between the shock waves produced at Wigwam and those from TNT or from refraction effects.

e. There were at least three bottom reflections, all attributable to the primary shock being reflected from successively deep bottom layers (Figs. 3.11 and 3.12).

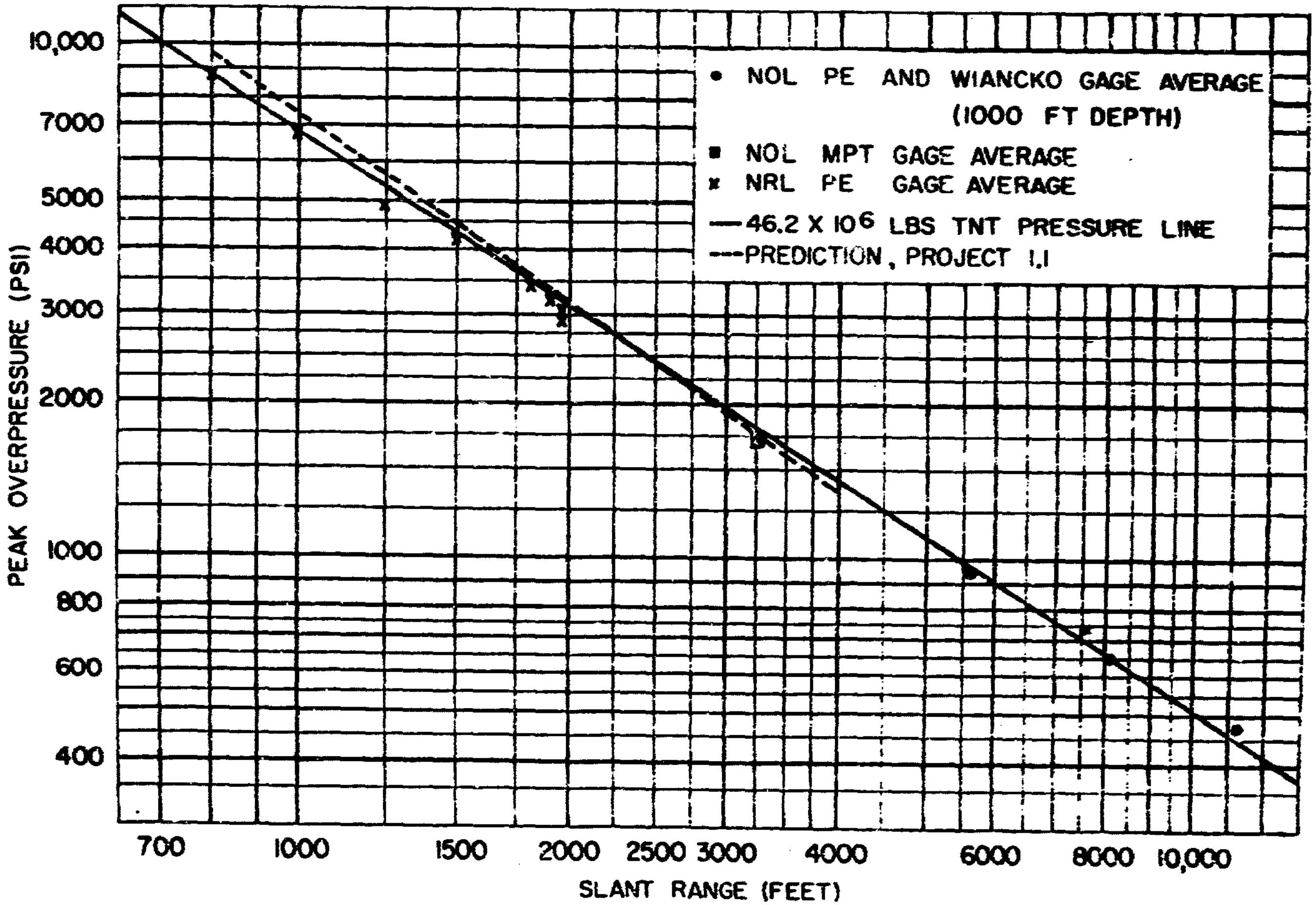

Fig. 3.8—Averaged Wigwam peak pressures compared with TNT.

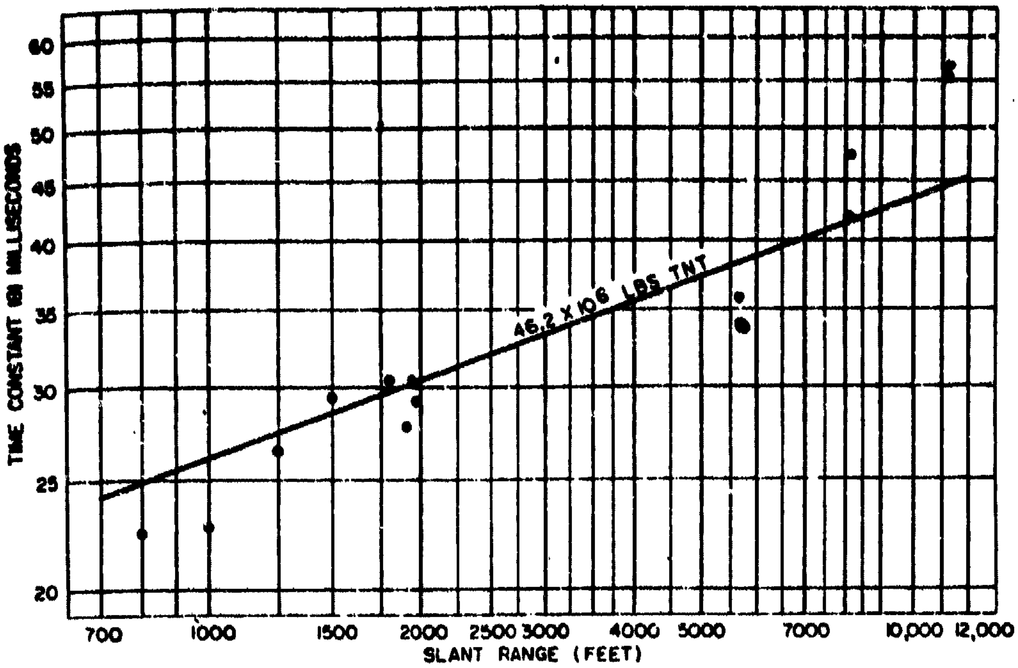

Fig. 3.9—Averaged Wigwam time constants for NOL and NRL stations.

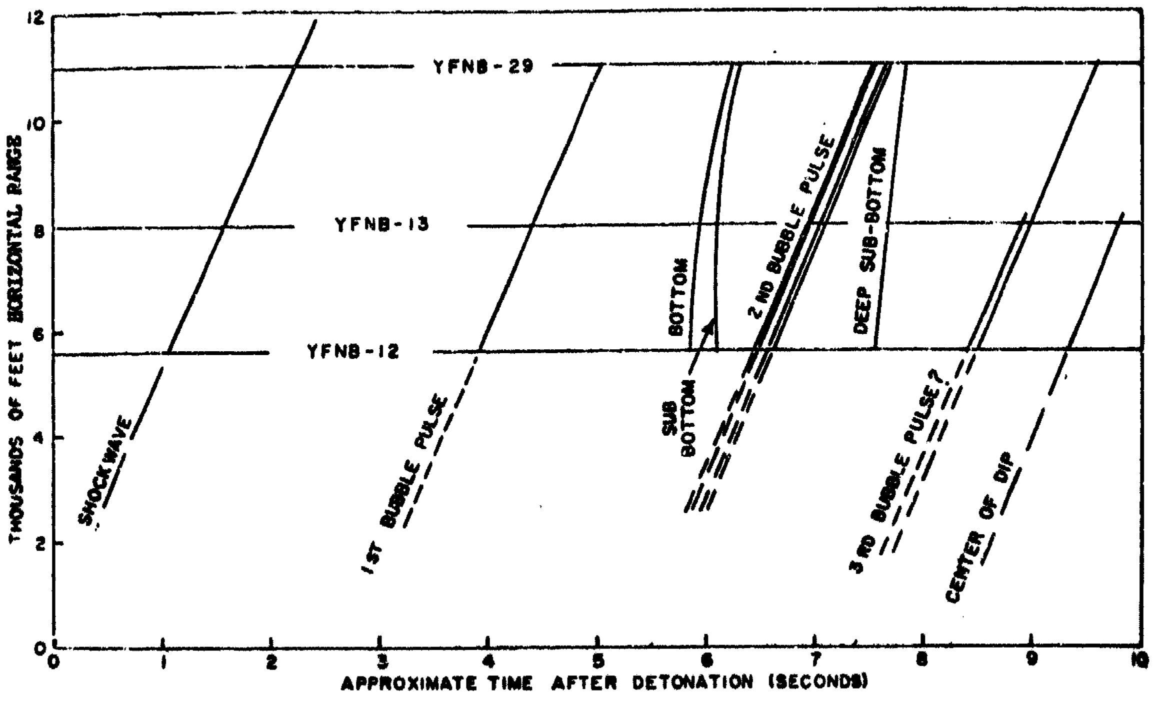

Fig. 3.10—Arrival times of pressures at 1000-ft gauges on YFNB's.

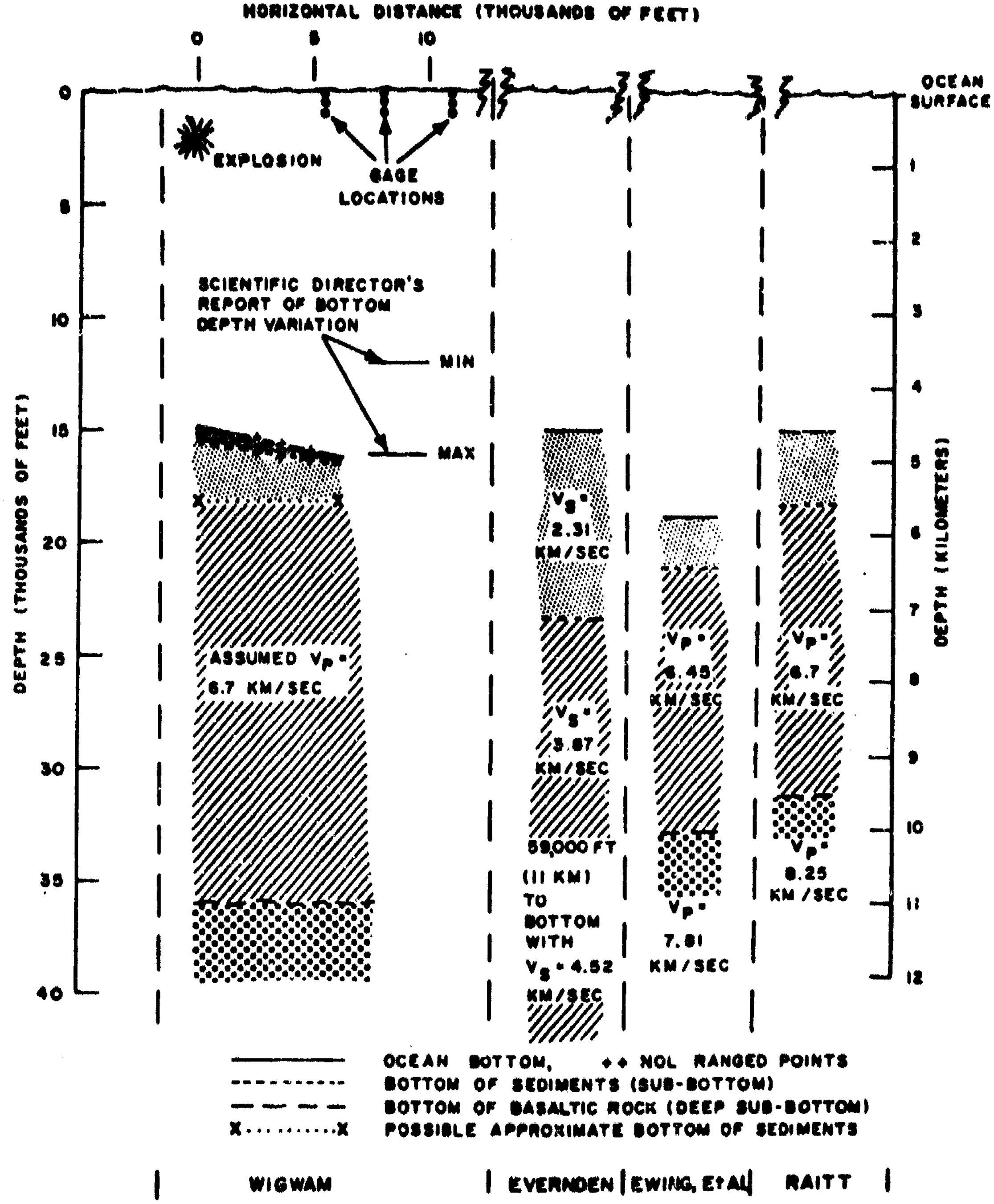

Fig. 3.11—Wigwam bottom structure and comparison with other locations and methods.

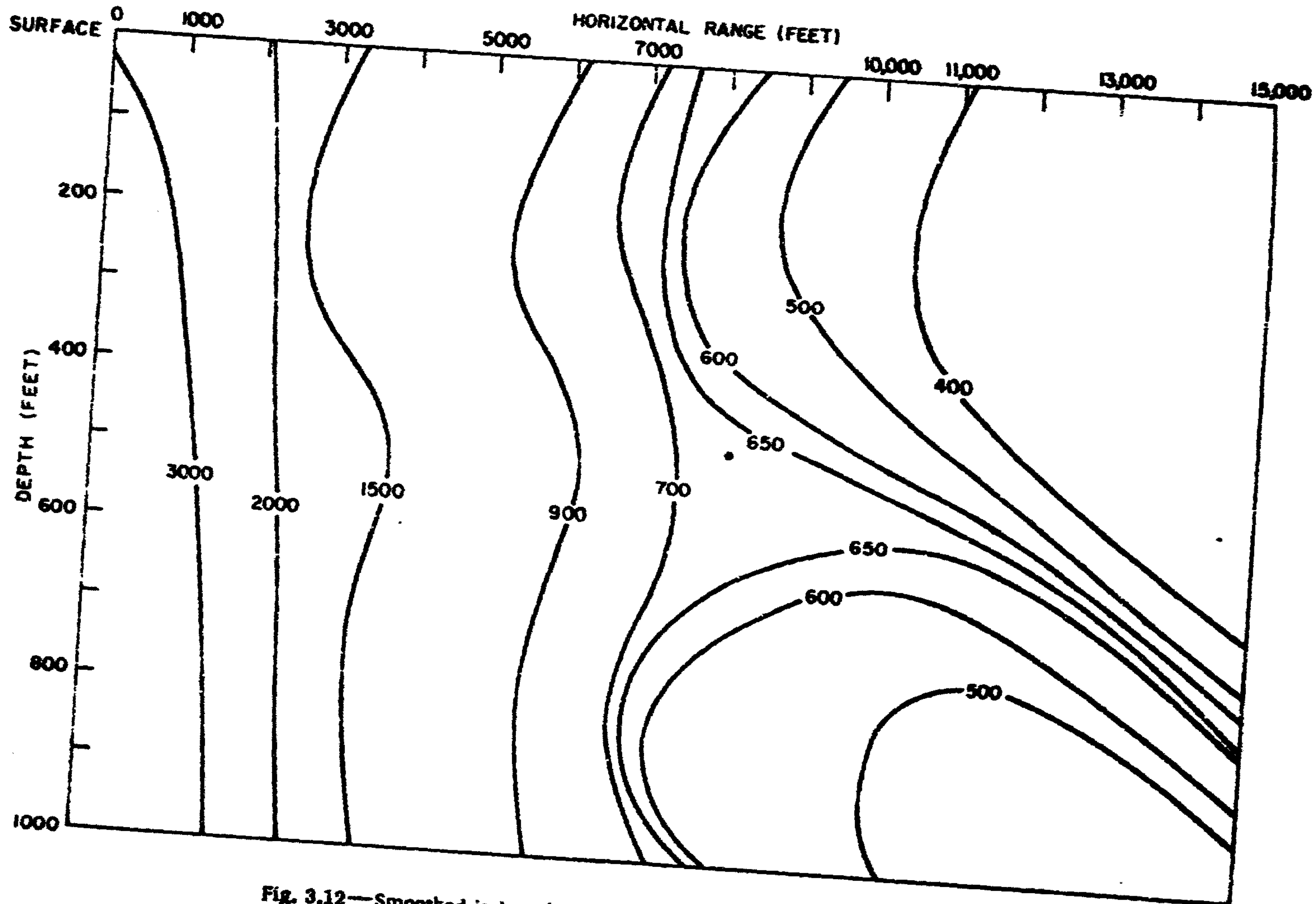

Fig. 3.12—Smoothed isobars (psi) based on NOL and NRL Wigwam data.

3. Recommendations

The free-floating buoy support system for ball-crusher gauges should be discarded or radically modified. The mechanical pressure-time gauges in conjunction with a free-floating wooden buoy and spar support system may be effectively used as primary measurement devices or as reliable backup instrumentation.

Piezoelectric linear amplifiers with wide ranges should be used in preference to logarithmic amplifiers. Unitized construction, possibly including printed circuits, is a valuable electronic technique. Trailers are highly satisfactory instrumentation shelters.

Planning for future similar type sea operations should include entirely new and much more rugged and simpler array-component-suspension and buoy-attachment methods. Ships should be used instead of LCM's if practicable.

No further testing or detailed instrumentation over the intermediate range is considered necessary at this time for similar yield devices.

Planning and execution of future sea tests should include detailed recovery assignments for each participating vessel or aircraft. If direct commands and firm plans are not practicable owing to communication limitations and the uncertainty of phenomenological effects, then doctrine sould be established as guides to the commanding officers involved.

PROJECT 1.2.1

TITLE: Free-Field Pressures, Station Zero (Operation Wigwam, WT-1006, Secret-RD, C. B. Cunningham)

PROJECT OFFICER: J. Paul Walsh

ORGANIZATION: U. S. Naval Research Laboratory, Washington 25, D. C.

1. Objective

Measure the characteristics of the shock wave in water from close-in to 2500 ft. To accomplish this objective, it was planned to measure pressures along a vertical line directly over the weapon and along a vertical line 2500 ft away from the first line. NRL assumed primary responsibility for obtaining data from the station directly over the weapon. Measurements at the 2500-ft station were a cooperative effort of NOL as Project 1.2 and NRL. Project 1.2 had the primary responsibility at the 2500-ft station, with Project 1.2.1 providing telemetering as a backup.

2. Results

Free-field pressures as a function of time were measured at eight positions above the Wigwam weapon at distances from the charge varying from 800 to 1975 ft. Tourmaline piezoelectric gauges were used. Signals were either telemetered to a remote receiving location or were recorded in place on a magnetic-tape recorder that was recovered after the shot (Figs. 3.13 and 3.14).

The variation of maximum observed pressure in pounds per square inch with distance in feet from the weapon in this range is given by the expression

$$P_{max} = \frac{2.03 \times 10^7}{R^{1.16}}$$

Impulse, at locations not affected by surface cutoff, is given by the expression

$$I = \frac{2.36 \times 10^4}{R^{0.77}}$$

where I is in pound-seconds per square inch.

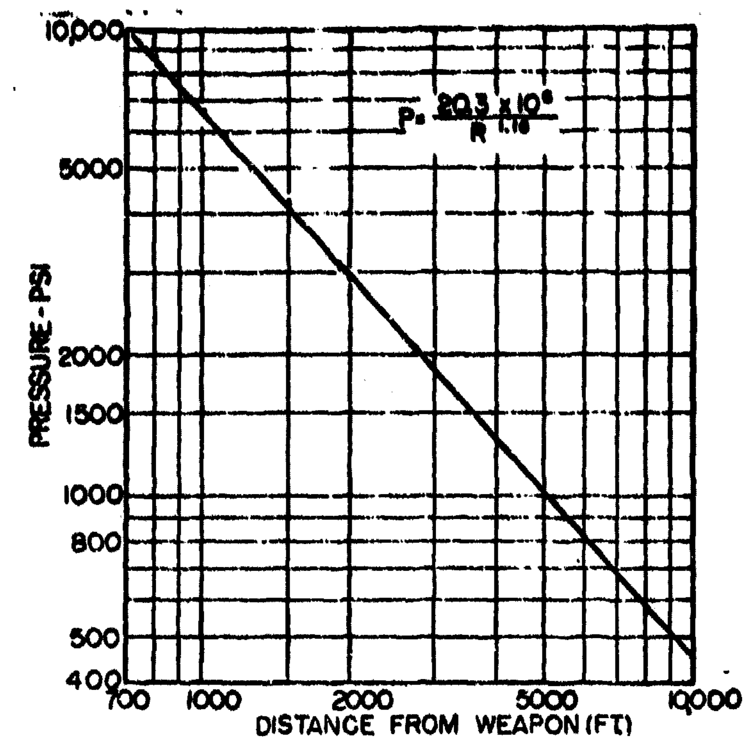

Fig. 3.13—Pressure vs distance from weapon.

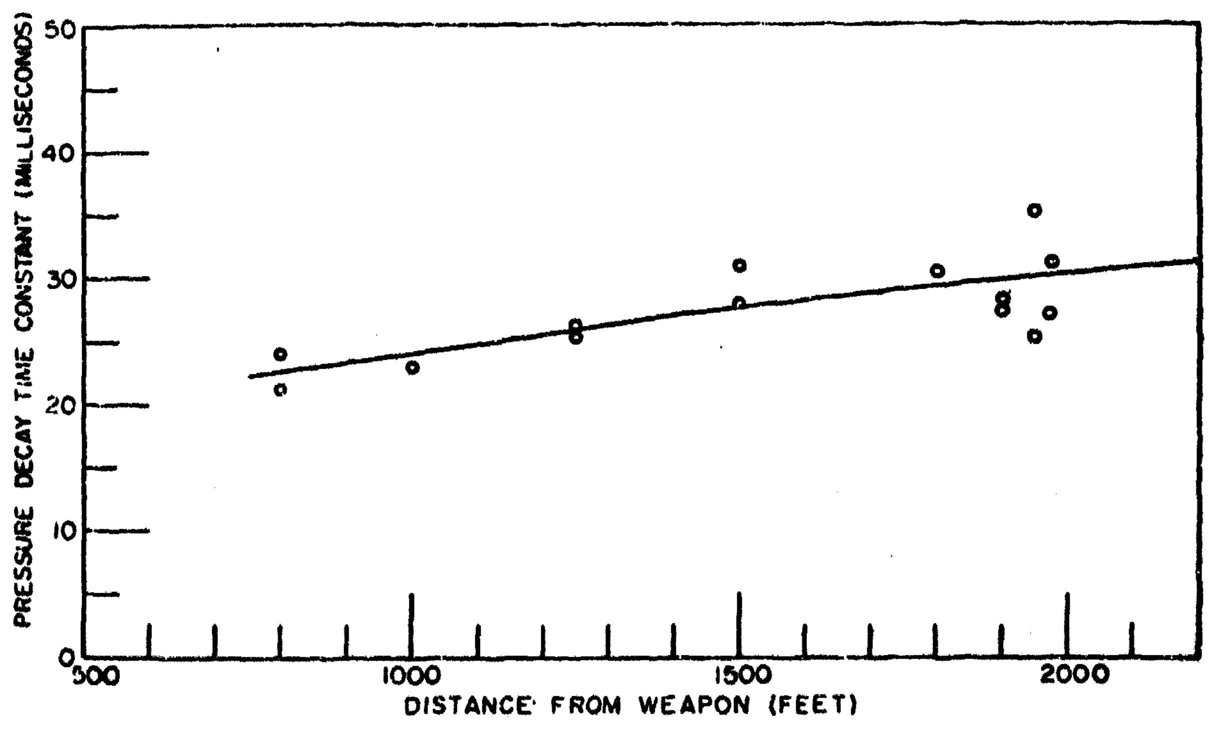

Fig. 3.14—Decay constant vs distance from weapon.

Energy flux density, at locations not affected by surface cutoff, is given by the expression

$$E = \frac{3.81 \times 10^{10}}{R^{1.87}}$$

where E is in inch-pounds per square inch.

The fiducial pulse was recorded at 12.5 ± 1 msec before weapon detonation. The shock wave arrived at the water surface 385.5 msec after the fiducial pulse (Fig. 3.15).

The equivalent weight of TNT required to produce the same peak pressures as the Wigwam weapon at 2000 ft was 4.05×10^7 lb.

3. Recommendations

Telemetering was successful because of frequent rehearsals and backing-up collecting and transmitting equipment. Similar methods are recommended for future operations. The accuracy of Edgerton, Germeshausen and Grier, Inc., timing data was questioned, and it is suggested that direct methods for time-of-firing determination be used.

PROJECT 1.3

TITLE: Underwater Free-Field Pressure Measurements (Operation Wigwam, WT-1007, Secret-RD, T. McMillian)

PROJECT OFFICER: Tom McMillian

ORGANIZATION: U. S. Navy Electronics Laboratory, San Diego, Calif.

1. Objective

Determine the free-field pressures as a function of time, depth, and range at distances greater than 5000 ft from a deep underwater atomic bomb burst and study the influence of refraction conditions, surface and bottom reflections, etc., on these pressures.

2. Results

Pressure-time records and peak-pressure records were obtained at 10 depths at each of four* stations (Figs. 3.16 to 3.19).

Average peak pressures at the three YFNB stations, at calculated ranges of 5505, 7943, and 10,923 ft, were 810, 590, and 430 psi, respectively. These are approximately the values expected from the explosion of 36,000,000 lb of TNT under the same conditions. Several smaller signals (amplitudes 3 to 7 per cent as large as those of the initial pulse) were received from the surface (apparently cavitation collapse) and from bubble pulses at a depth of approximately 1600 ft. The first bubble pulse was generated 2.78 sec after the burst.

Measurements near the surface indicated that more than 80 per cent of the energy was reflected from that boundary. The amount of energy in the surface-reflected signal decreased rapidly as the depth of the measuring gauge increased, and this effect became more pronounced at shorter ranges. The amplitudes of the bottom-reflected signals were approximately 20 per cent as large as they would have been had they traveled the same distance without reflection.

Under conditions of this test, refraction may largely determine shock-wave pressures at ranges greater than 10,000 ft. Computations indicate that shock-wave pressures of over 800 psi may have existed at a range of 17,000 ft (in this particular case at a depth of approximately 1000 ft), where the expected pressures without refraction would have been 250 psi.

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*Seven stations were to be used, but, owing to rough weather, three of the stations installed on LCM's could not be used. For the same reason the fourth LCM station, adjusted for operation at 15,000 ft, had to be operated at a range of approximately 7 miles.

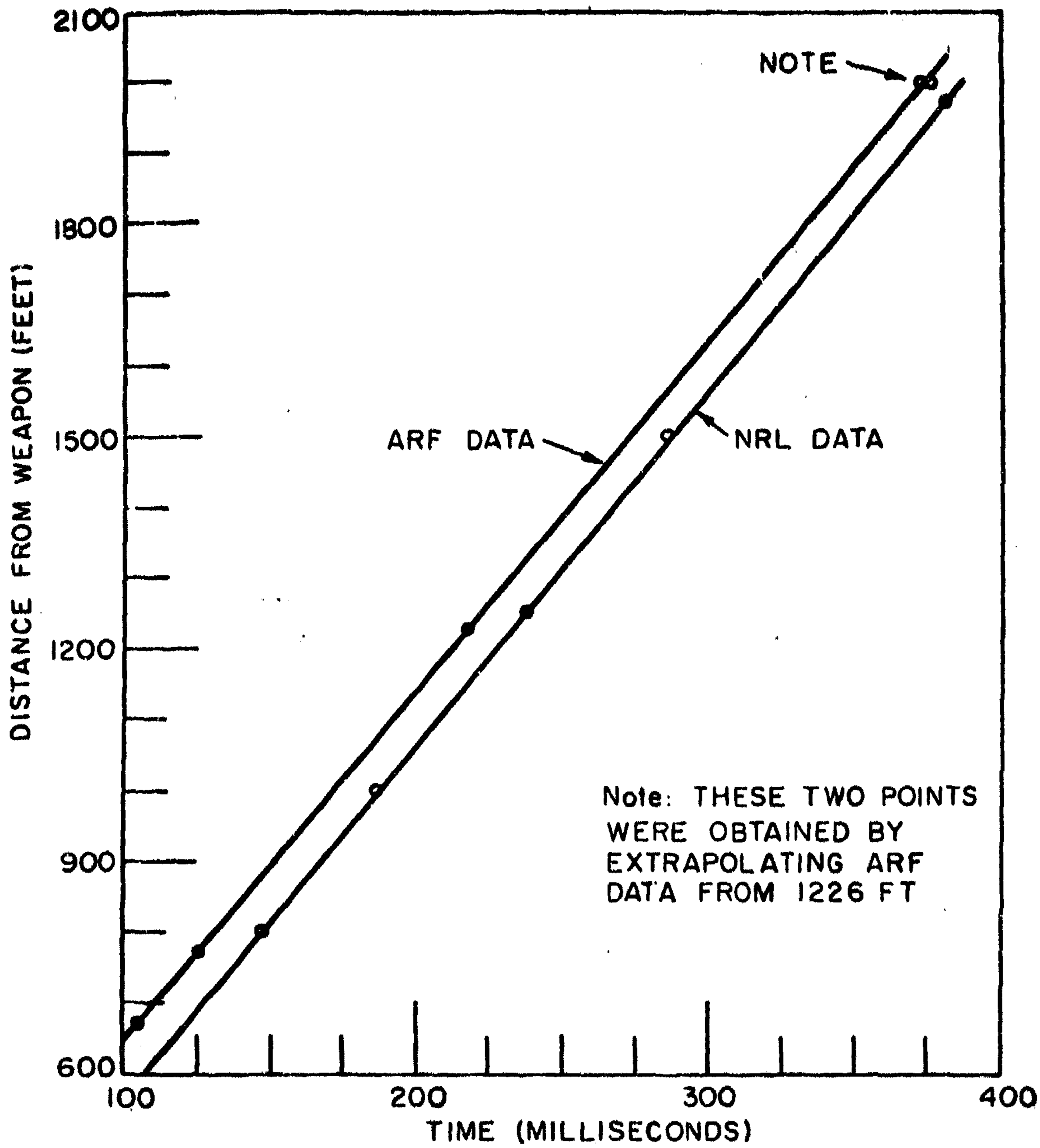

Fig. 3.15—Shock-wave arrival times.

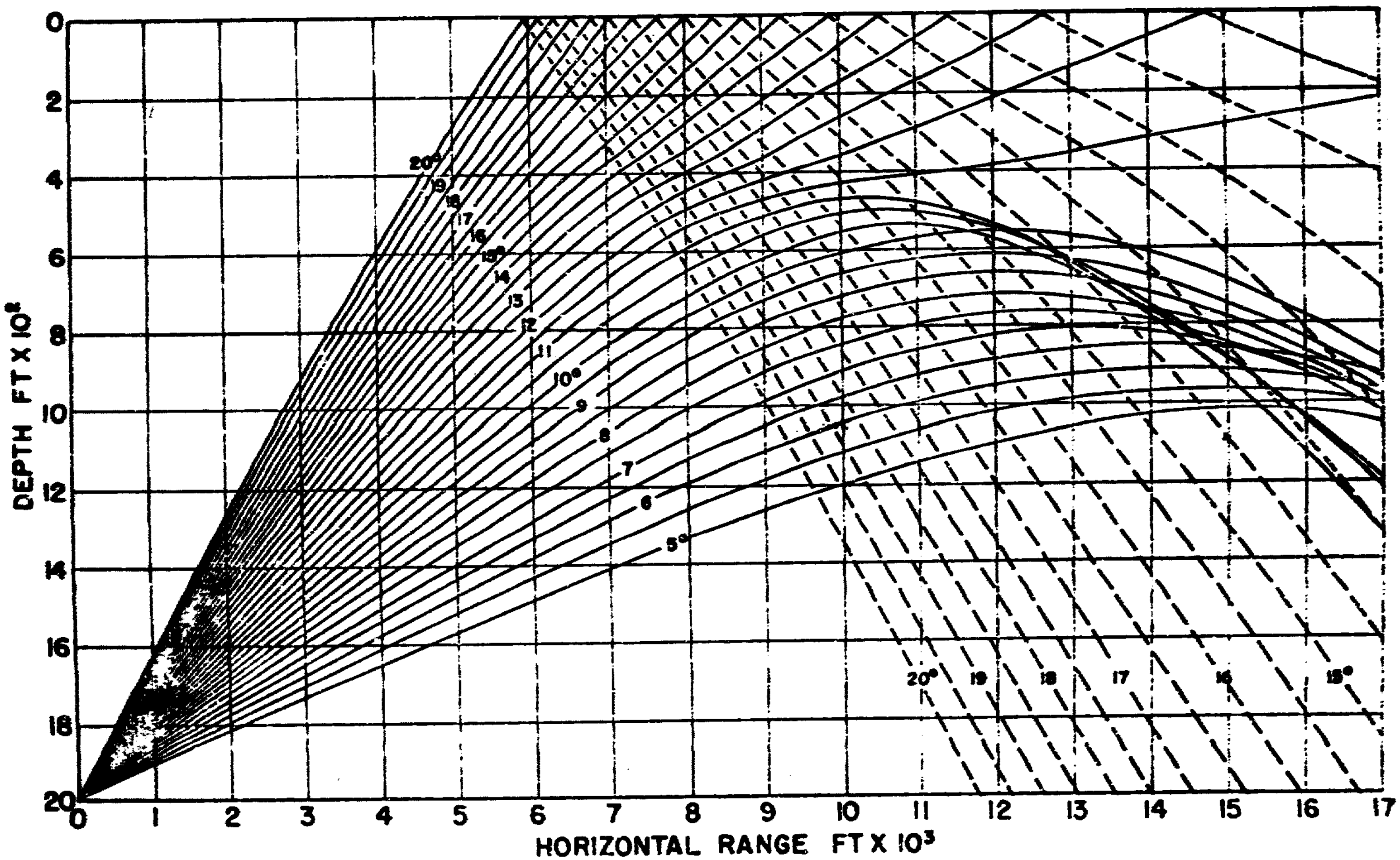

Fig. 3.16—Ray diagram for Wigwam operating area.

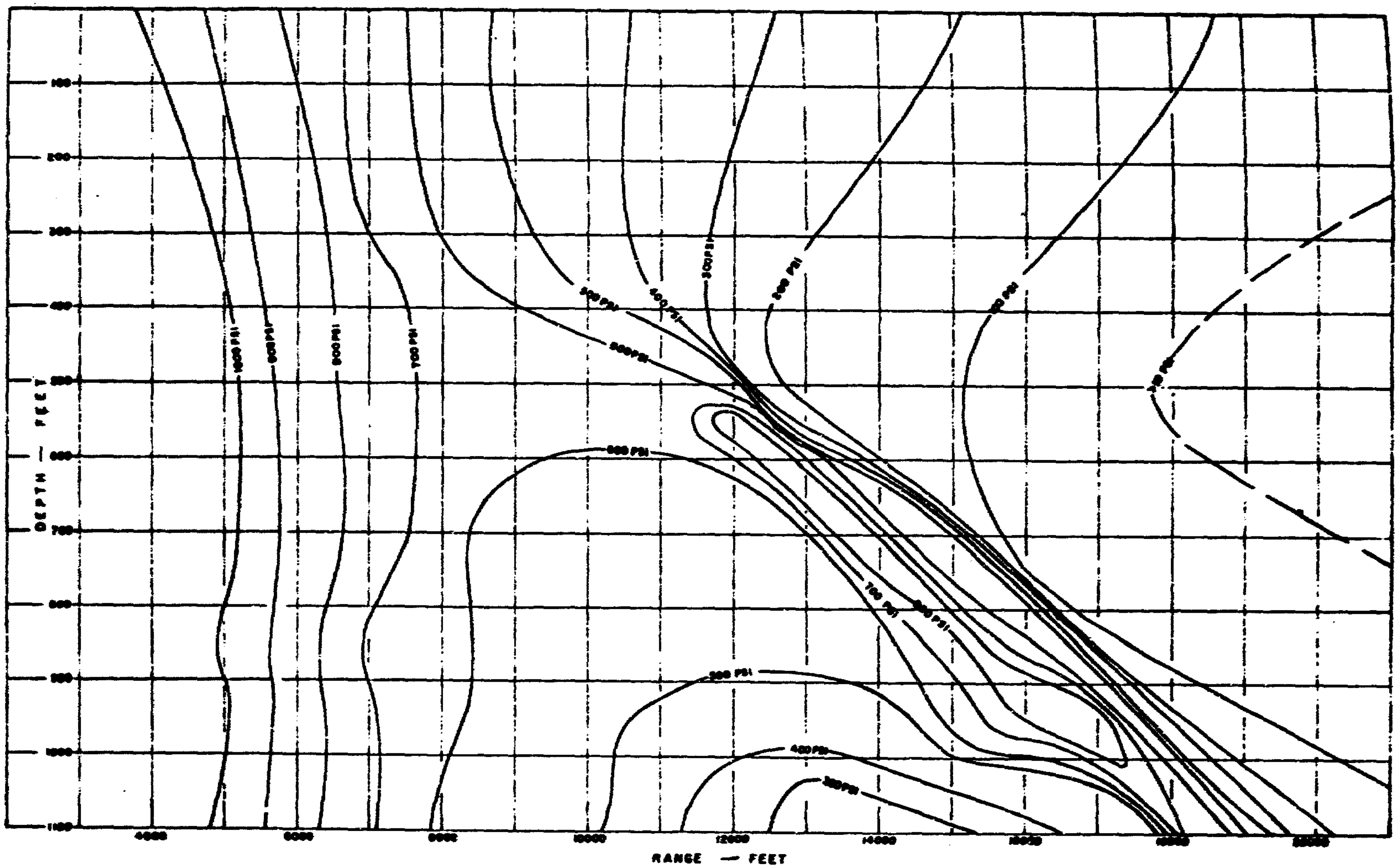

Fig. 3.17—Peak-pressure contour chart.

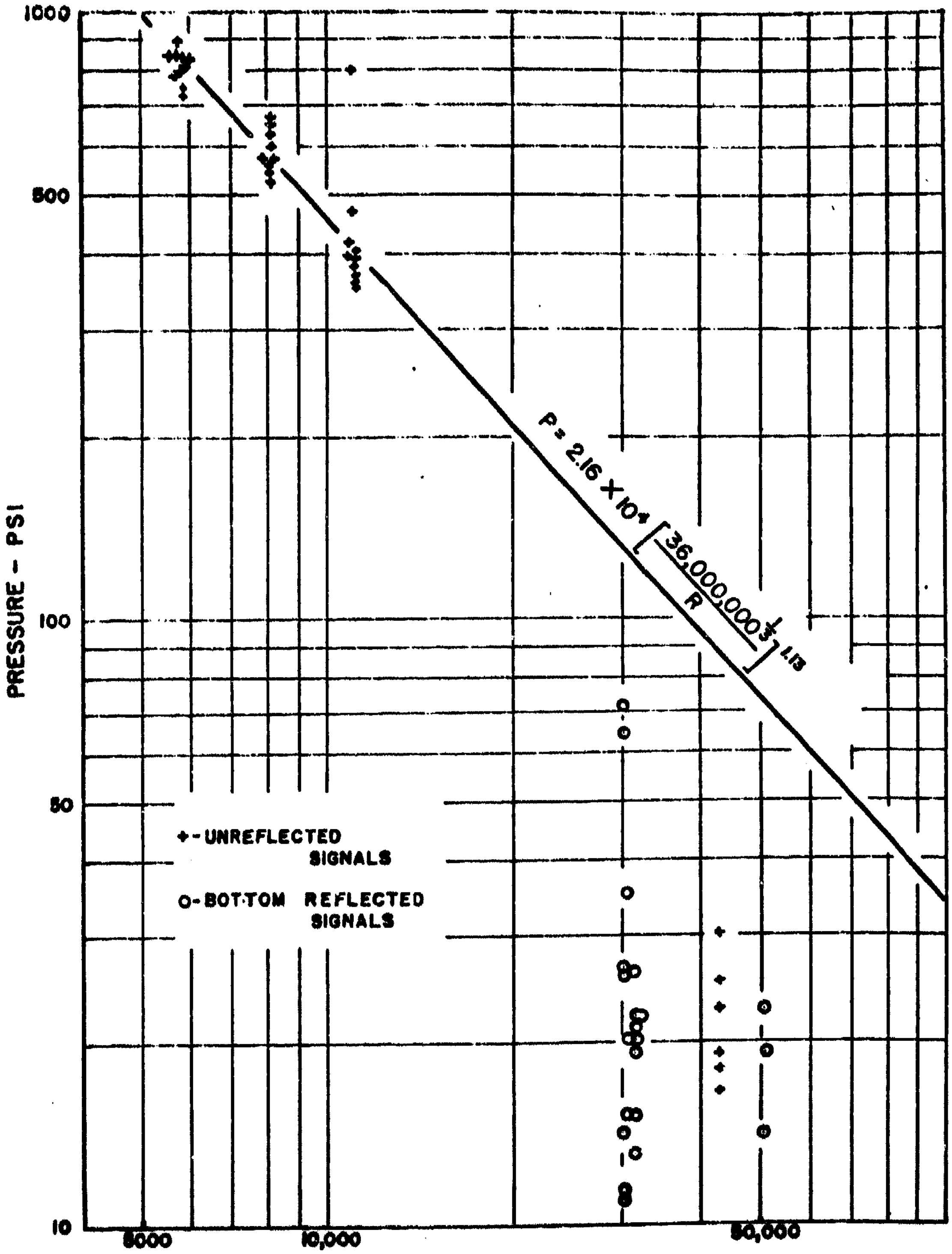

Fig. 3.18—Measured peak shock-wave pressures as a function of travel distance.

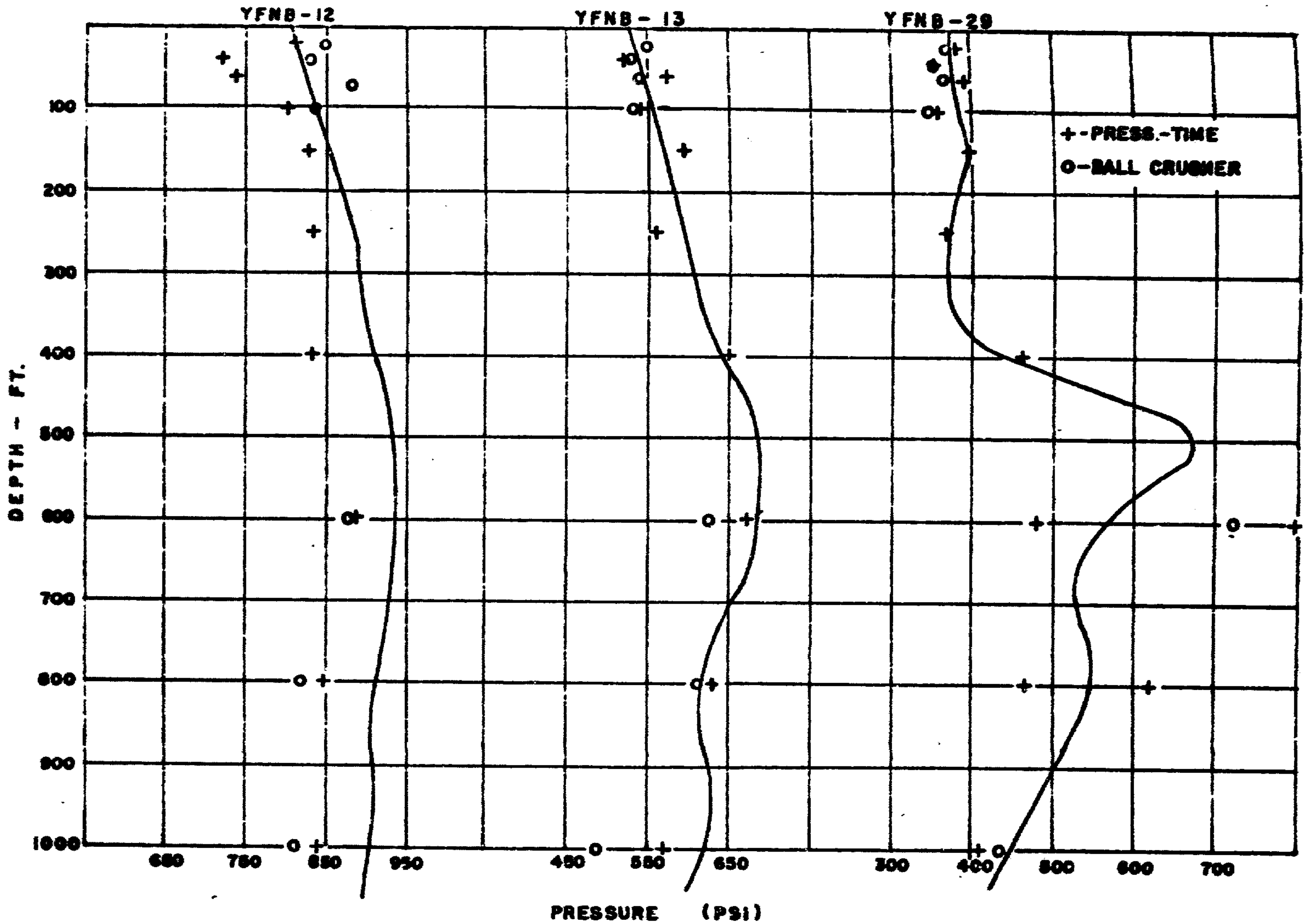

Fig. 3.19—Peak shock-wave pressure vs depth at YFNB stations.

3. Recommendations

Since refraction may greatly extend the lethal range for submarines under atomic attack and since weather conditions prevented making measurements in the critically affected region during Wigwam, it is strongly recommended that a test be scheduled to permit such measurements at the earliest possible date.

PROJECT 1.4

TITLE: Bubble Phenomena (Operation Wigwam, WT-1008, Confidential-RD, G. R. Hamilton, G. B. Tirey, and Peter Hanlon)

PROJECT OFFICER: C. J. Aronson

ORGANIZATION: Explosives Research Department, U. S. Naval Ordnance Laboratory, White Oak, Silver Spring, Md.

1. Objectives

a. Measure the energy of the radial flow of water associated with the explosion bubble by a determination of the maximum water displacement.

b. Measure the period and maximum radius of the bubble.

2. Results

Two stations were to be utilized for lowering water-displacement meters a depth of 2000 ft. At one station a winch failed, and there was not time to clear it because of bad weather. At the second station rough seas caused enough direct and indirect damage to prohibit lowering of the instruments. No useful data were obtained.

3. Recommendations

The following recommendations are made to improve the reliability of the water-displacement meter as an instrument for one-shot tests similar to Wigwam:

a. Test various methods of suspending, with shock mounting, the water-displacement meter from a float to reduce the motion of the camera sphere (Figs. 3.20 and 3.21).

b. Evaluate the hevimet reference sphere, and, if possible, omit it from the apparatus to reduce the motion of the camera sphere.

c. Develop objects to indicate particle displacement other than the oil drops, such as small, solid, neutrally-buoyant spheres of plastic or vanes.

d. Make improvements to the general instrumentation to simplify its operation and increase its reliability.

PROJECT 1.5

TITLE: Photographic Measurements of Surface Phenomena (Operation Wigwam, WT-1009, Confidential-RD, G. A. Young, J. F. Goertner, and R. L. Willey)

PROJECT OFFICER: C. J. Aronson

ORGANIZATION: Explosives Research Department, U. S. Naval Ordnance Laboratory, White Oak, Silver Spring, Md.

1. Objectives

Study the slicks, spray domes, plumes, base surge, and residual cloud by means of timed technical photography. Also, measure any other important visible effects that appear.

A secondary objective was to compare the Wigwam results with high-explosive data in order to check explosion theories and to determine if simple scaling relations could be es-

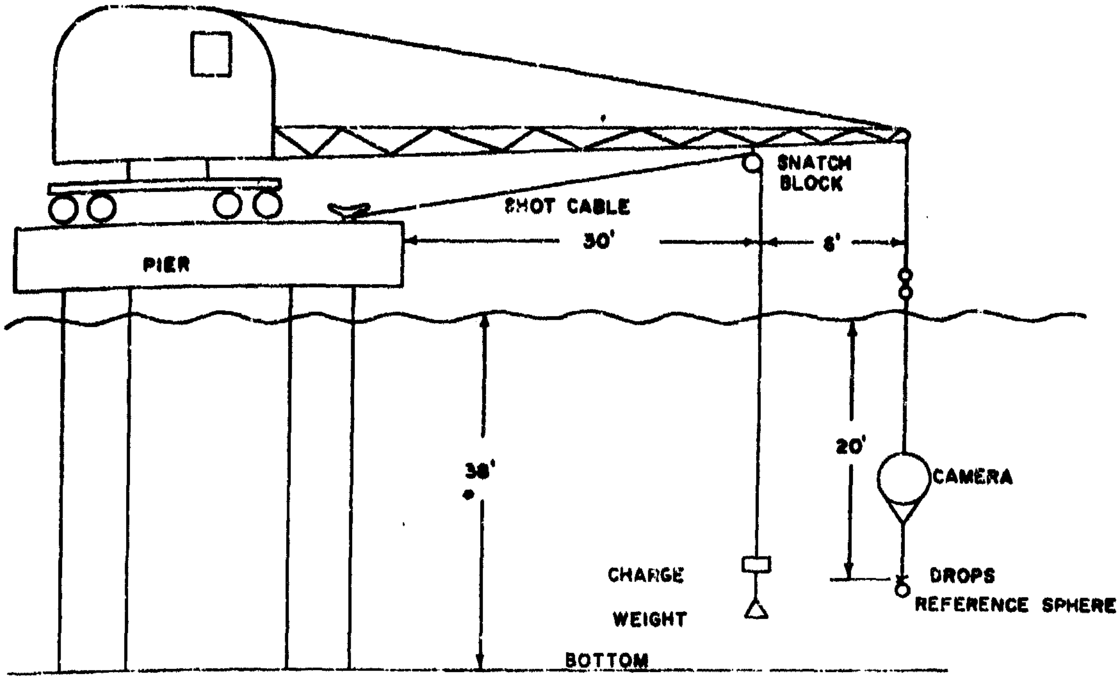

Fig. 3.20—Water-displacement-meter test rig for a 1-lb TNT charge suspended from a pier.

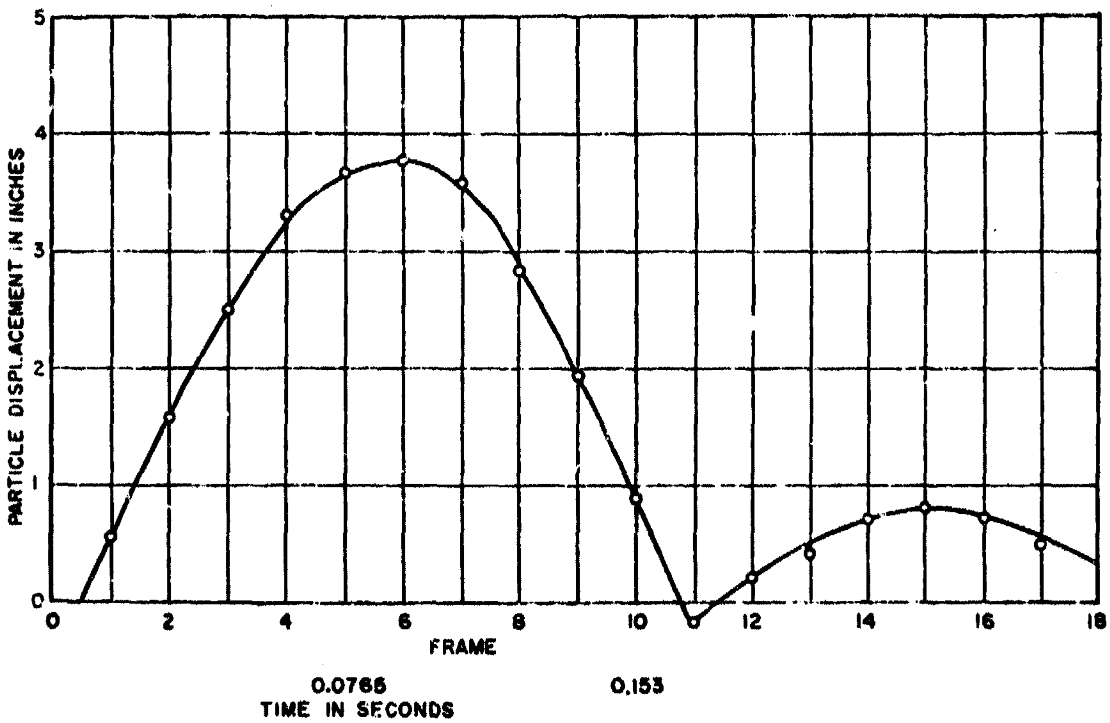

Fig. 3.21—Motion of a suspended oil drop near an underwater explosion, Test Group I. Charge size, 1 lb of TNT; charge depth, 21 ft; charge-to-drop distance, 66 in.

tablished which would be useful for the prediction of the surface effects of relatively deep nuclear detonations over a range of yields and depths.

2. Results

The visible surface phenomena of the nominal 30-kt nuclear weapon exploded underwater at a depth of 2000 ft were measured photographically. The most important results are illustrated in Figs. 3.22 through 3.35. The direct underwater shock wave produced a slick with a 14,000-ft radius and a spray dome with a 7000-ft radius and a central height of 170 ft. The velocity of rise of the spray dome at the center was 115 ft/sec, which was 33 per cent higher than expected on the basis of high-explosive results. The first bubble pulse produced a spiky second dome which reached a height of 900 ft. Peak air shock pressures, calculated from shock velocities, indicated an overpressure at Surface Zero of 4.43 psi. Possibly large measurement errors, however, make this value questionable. The negative phase of the air shock wave produced a cone-shaped condensation cloud with its base at 700 ft and top at 2600 ft. The bottom-reflected shock wave formed a distinct slick which grew to a radius of at least 34,000 ft. Scattered patches of spray appeared after the arrival of the slicks to a radius of 17,000 ft. These may be important in regard to ship damage and are relatively unpredictable since they are caused by shock reflection from irregularities in the ocean floor.

Plumes appeared at 10 sec, reached a height of 1450 ft and a diameter of 3100 ft, and then spread laterally to form a large base surge. The surge expanded to a radius of 4600 ft at H+90 sec and to possibly more than 7000 ft at H+15 min. The maximum observed height was 1900 ft at H+4 min, after which time the surge cloud was not visible on surface camera records.

Maximum wave height was 37 ft at a distance of 5520 ft from Surface Zero and decreased linearly with the reciprocal of distance.

The foam ring, which probably showed the extent of contaminated surface water, was measured until H+13 min, when it had reached a diameter of 10,400 ft.

3. Recommendations

a. On future operations a separate project should be established to obtain position-vs-time data for surface craft and aircraft by means of radar.

b. Battery power should be used for cameras mounted on ships.

c. Photography should be fully used as a data-collection technique.

d. Spray-dome phenomena need additional study.

e. It is essential that further study of plume and base-surge effects be prosecuted.

f. Additional work in the field of explosive-generated surface waves is badly needed.

PROJECT 1.6

TITLE: Underwater Optical Measurements (Operation Wigwam, ITR-1086, Confidential-RD, Dr. W. J. Thaler) (Interim report ITR-1086 will not be reprinted and is considered final)

PROJECT OFFICER: Dr. W. J. Thaler

ORGANIZATION: Office of Naval Research, Washington, D. C.

1. Objectives

Measure the time duration and magnitude of the underwater light pulse in order to:

a. Document the history of the underwater fireball.

b. Attempt to utilize the data obtained for calculating the yield of the weapon.

c. Estimate the usefulness of this technique for determining the yield of future detonations.

d. Attempt, by working back from the intensity and duration data, to calculate the temperatures of the shock wave (a close-in condition).

(Text continues on page 88.)

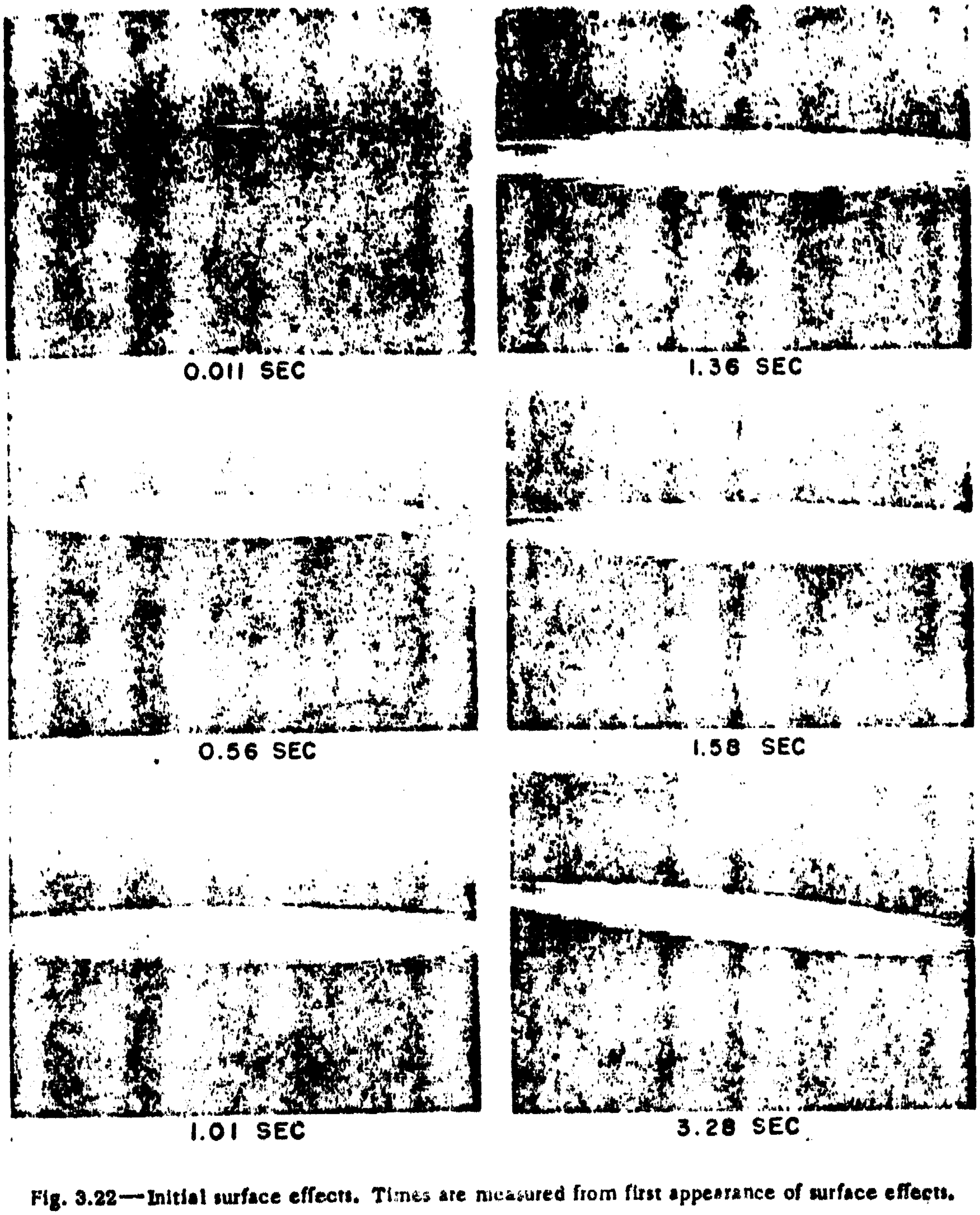

Fig. 3.22—Initial surface effects. Times are measured from first appearance of surface effects. Camera G-3.

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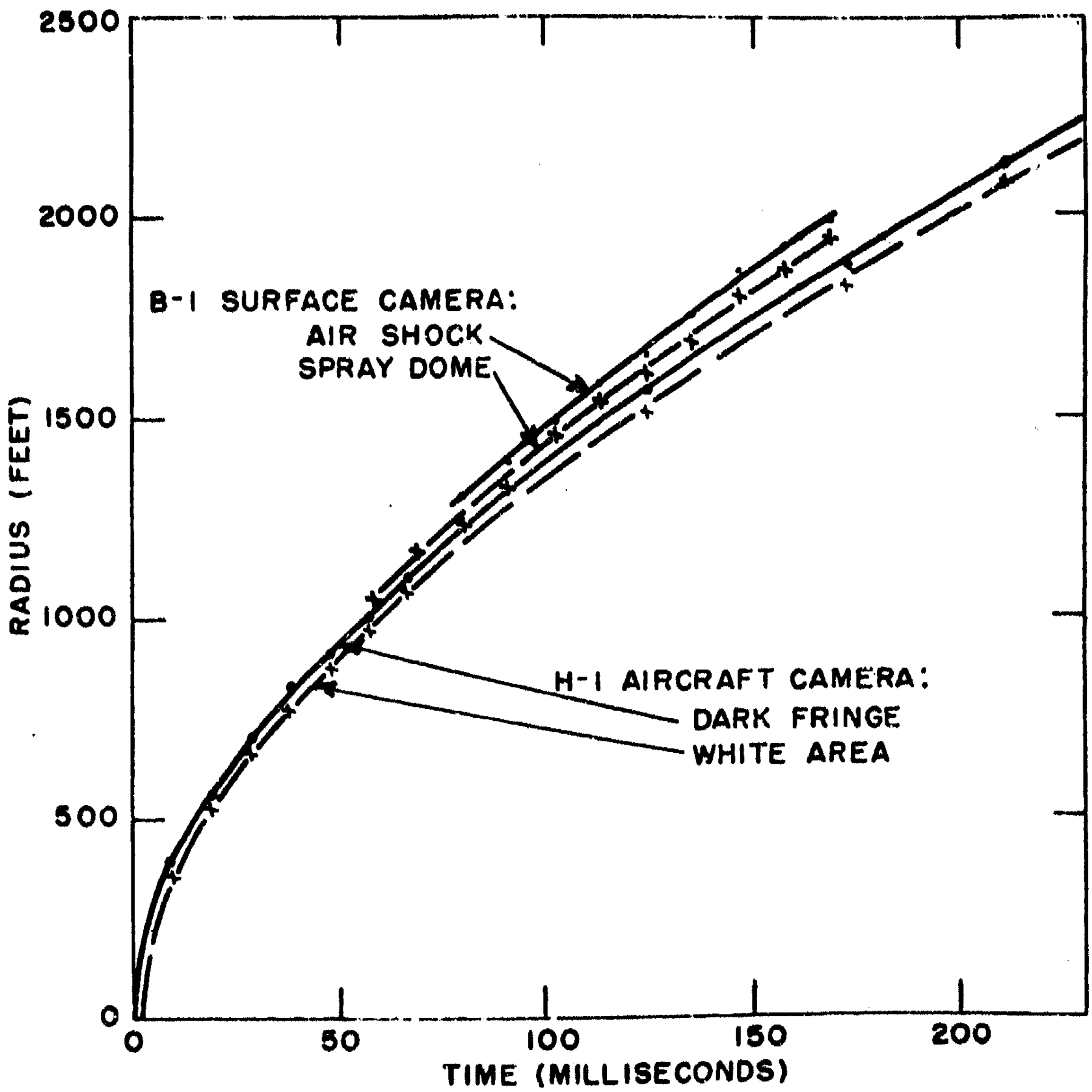

Fig. 3.23—Spread of direct shock-wave effects. Time is measured from first appearance of surface effects.

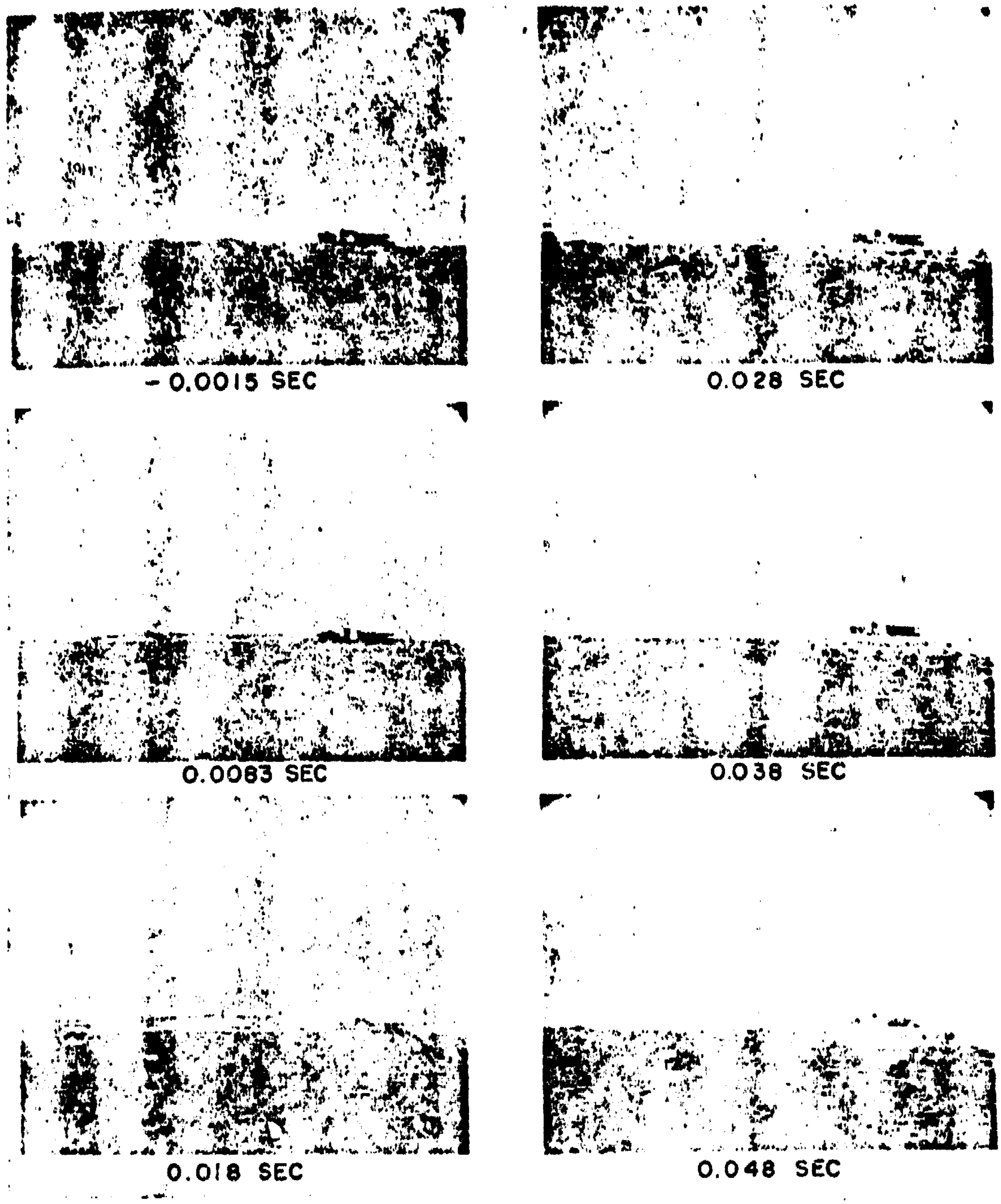

Fig. 3.24—Air shock wave. Times are measured from first appearance of surface effects. Camera E-5.

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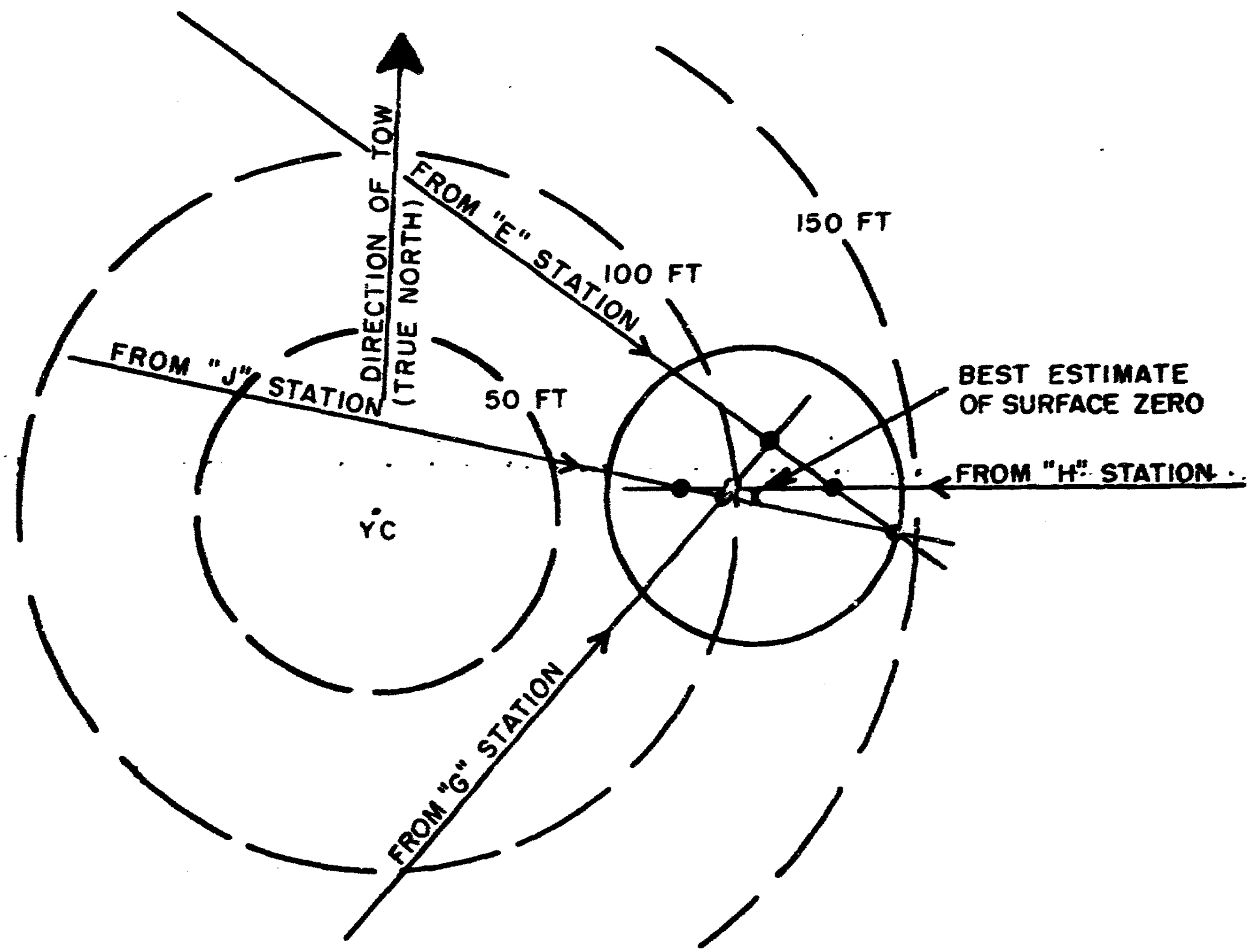
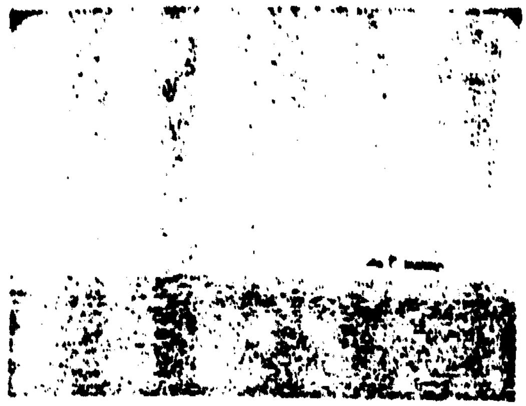
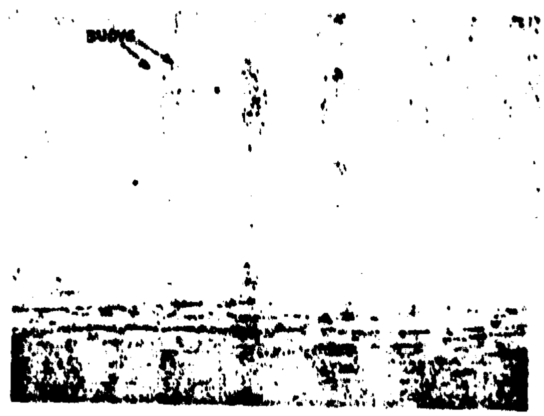


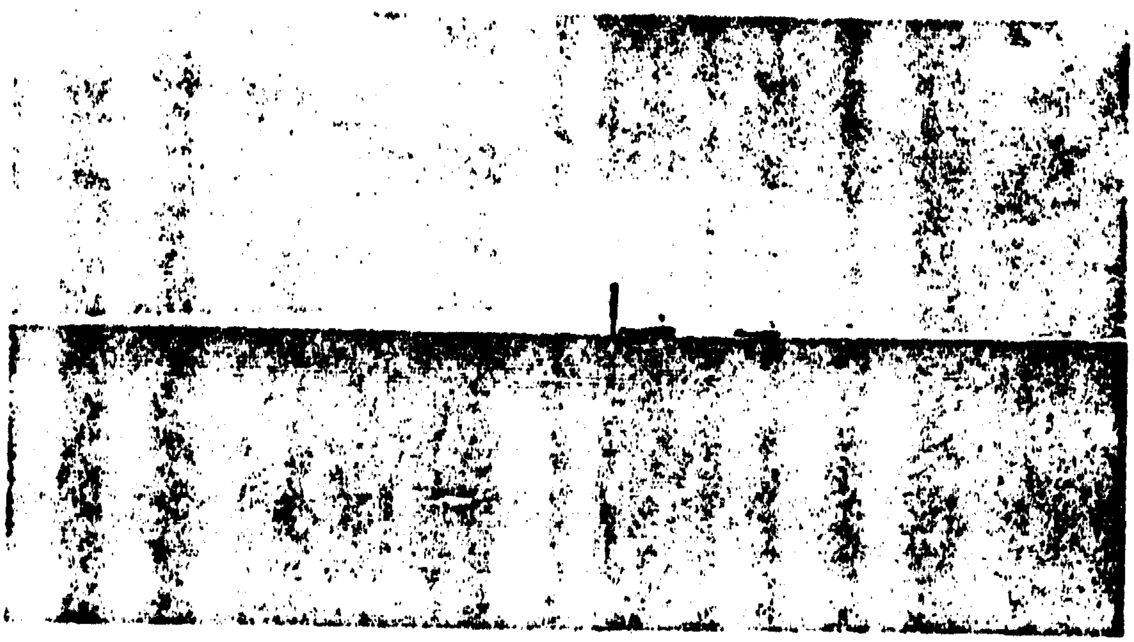
Fig. 3.25—Position of weapon in relation to well of YC-473.



CAMERA E-5 0.12 SEC



CAMERA G-2 0.82 SEC



CAMERA C-3 2.0 SEC

Fig. 3.26—First spray dome. Times are measured from first appearance of surface effects.

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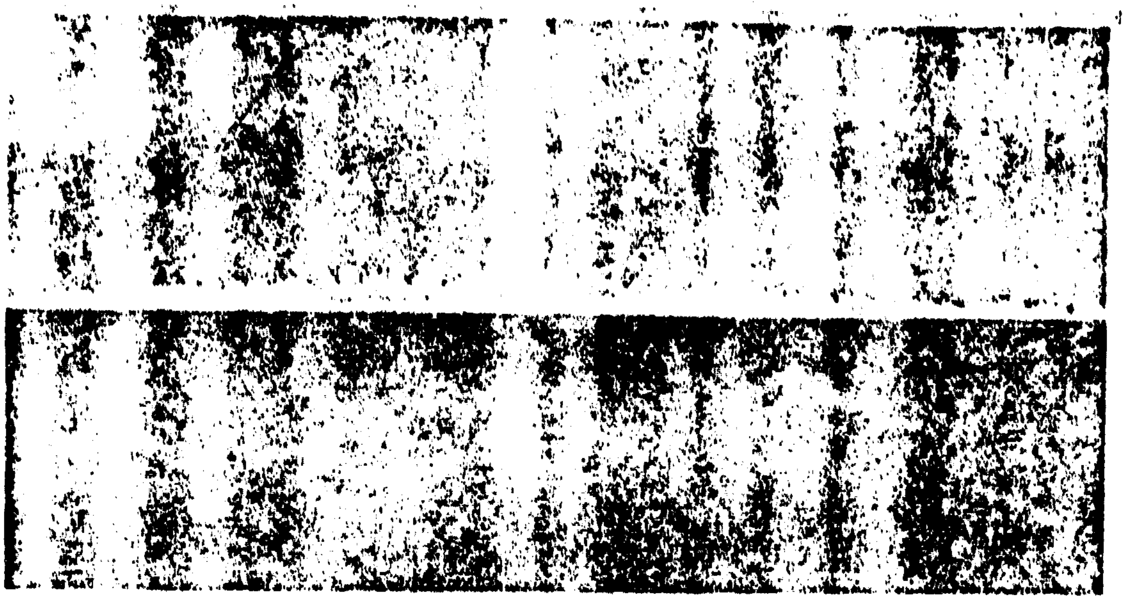

3.0 SEC

CAMERA E-3 A

6.0 SEC

Fig. 3.27—Second spray dome. Times are measured from first appearance of surface effects.

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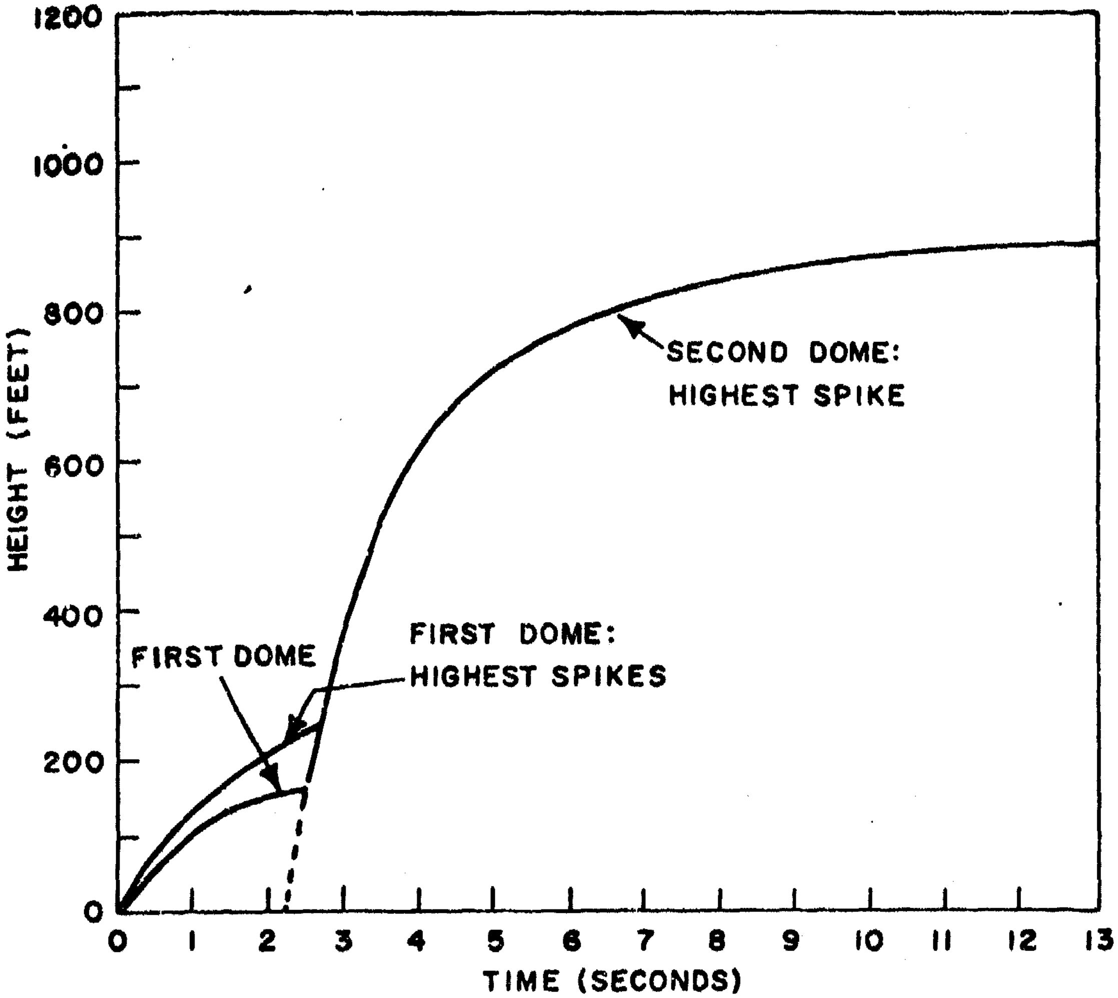

Fig. 3.28—Height of spray domes vs time. Times are measured from first appearance of surface effects.

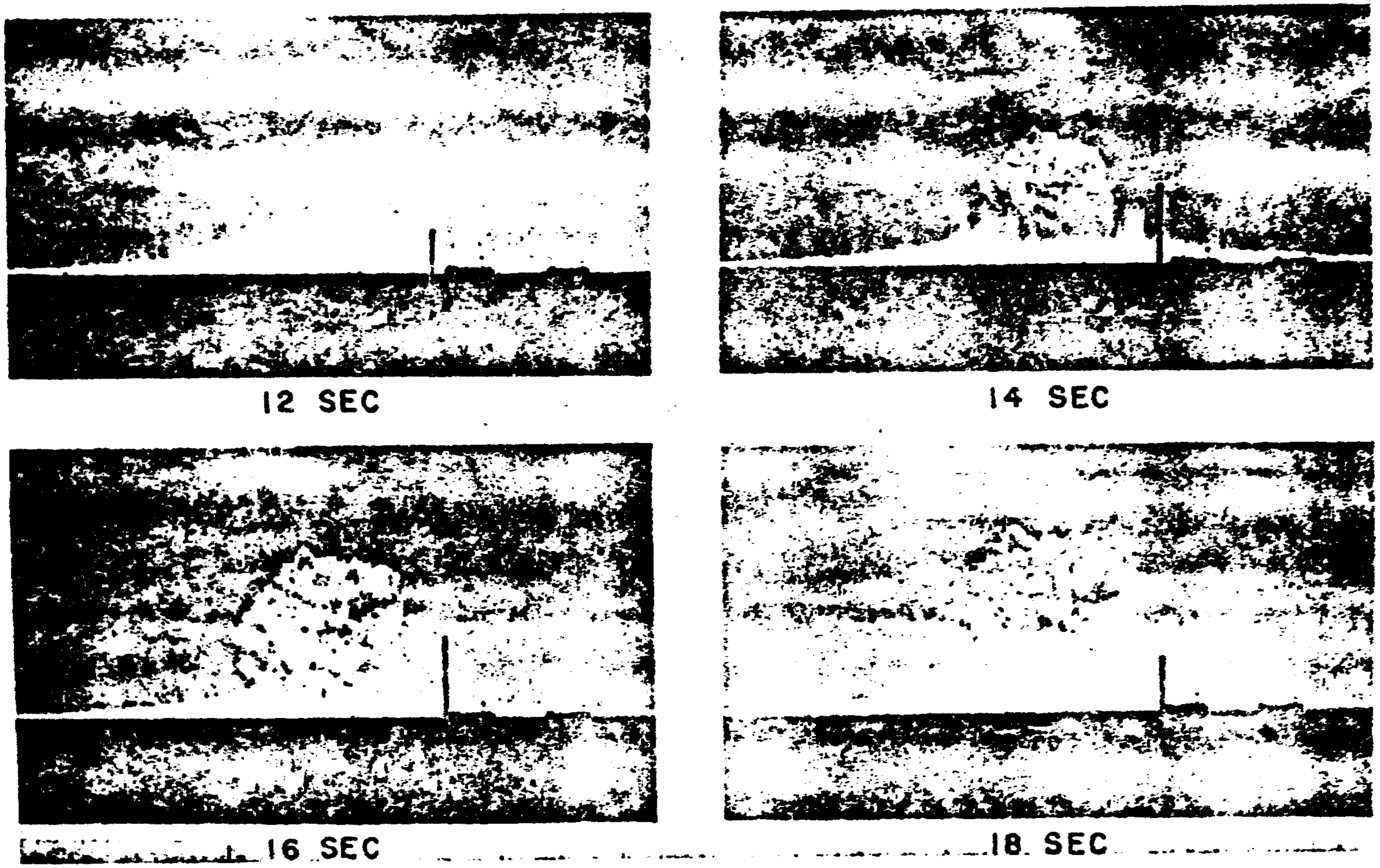

Fig. 3.29—Plume formation. Times are measured from first appearance of surface effects. Camera C-3.

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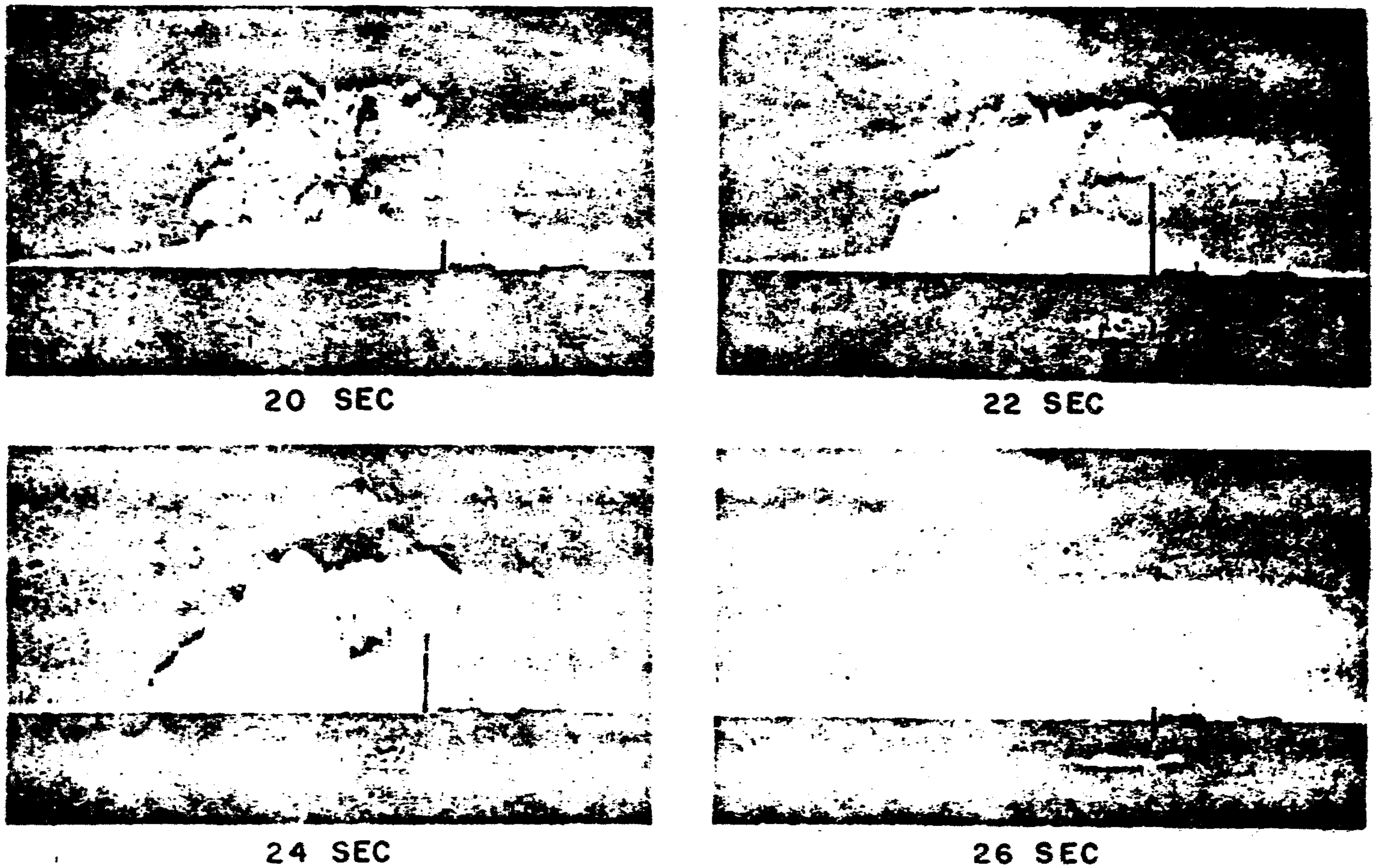

Fig. 3.30—Plume collapse. Times are measured from first appearance of surface effects. Camera C-3.

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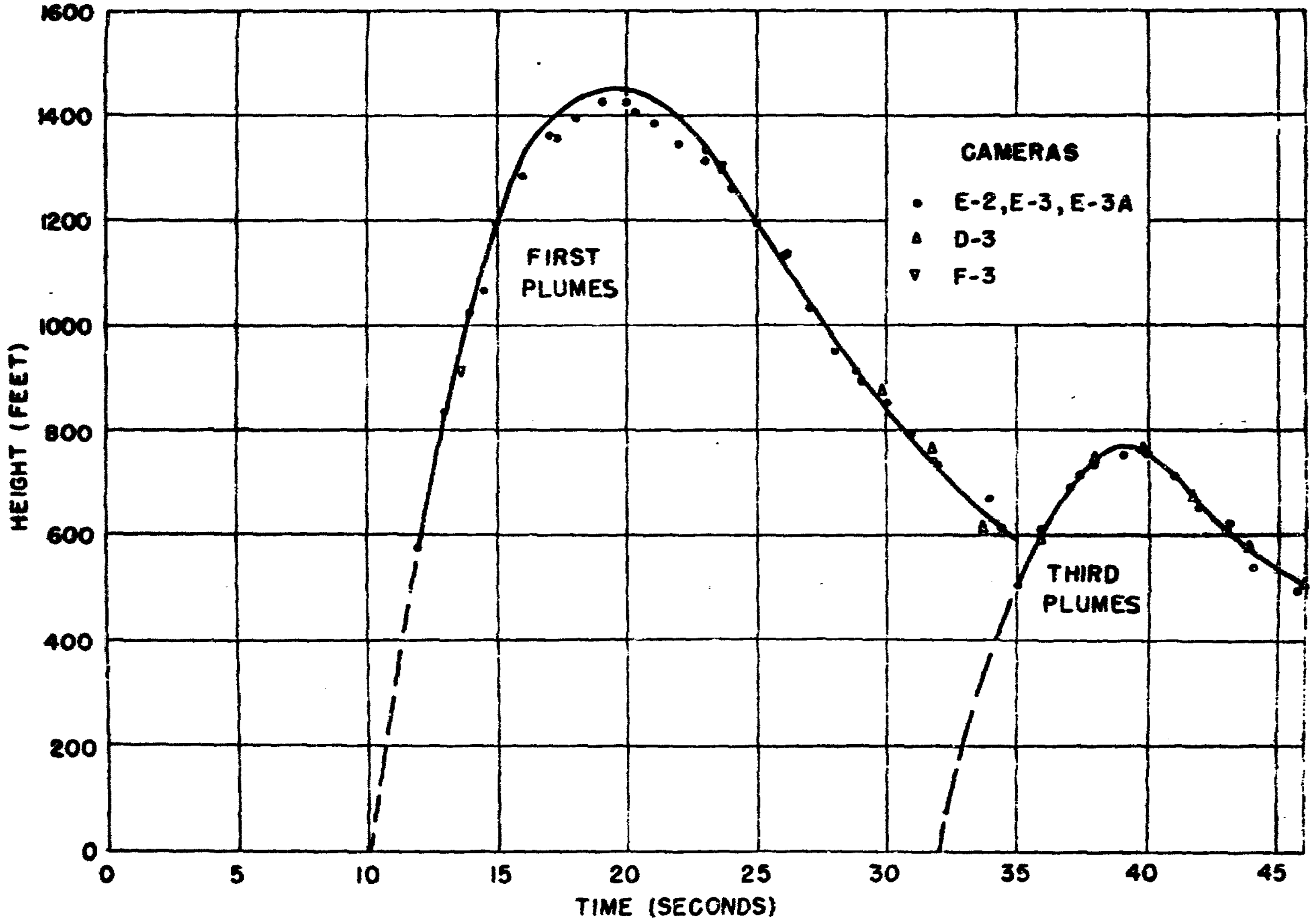

Fig. 3.31 —Plume height vs time. Times are measured from first appearance of surface effects.

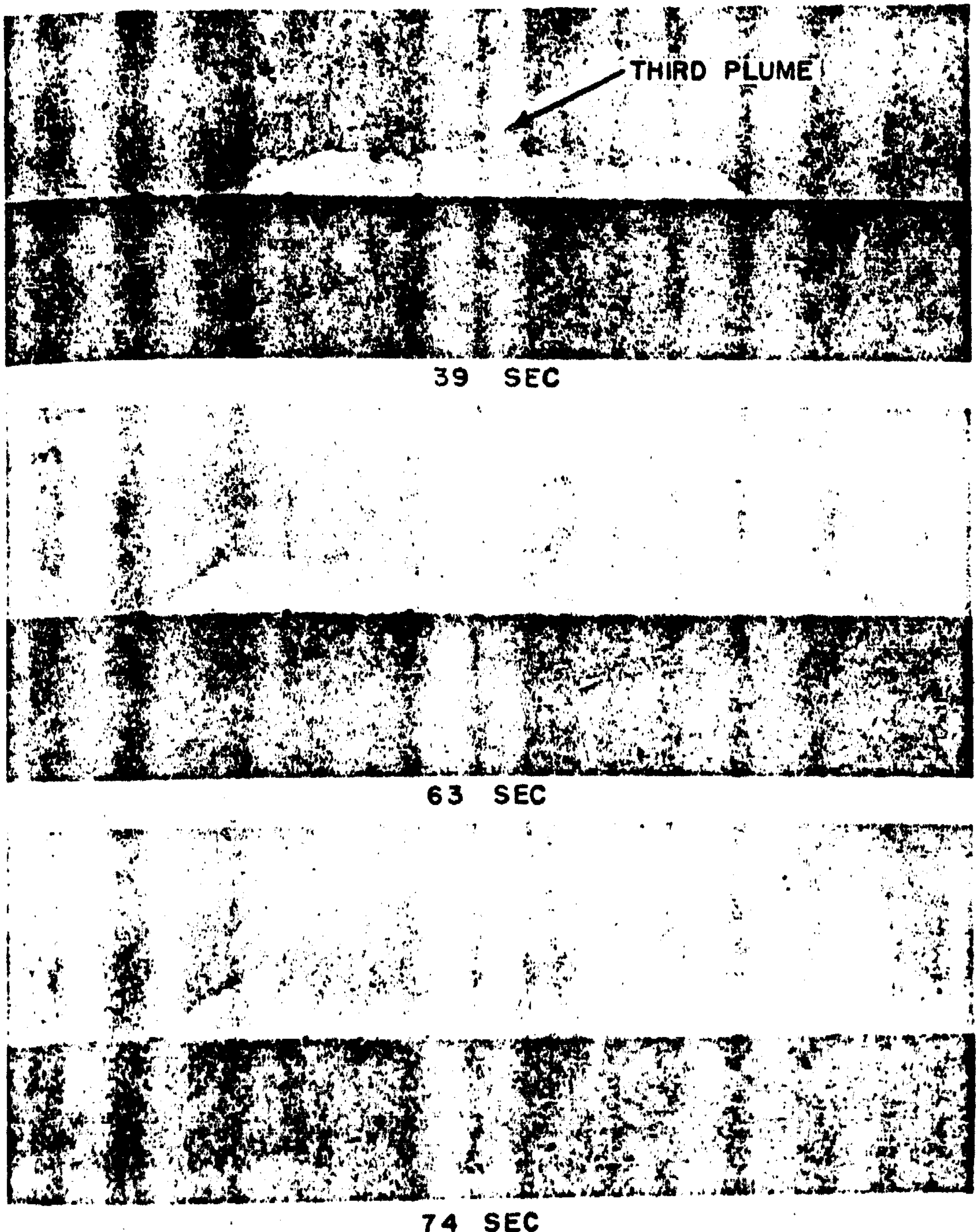

Fig. 3.32—Base surge at early times. Times are measured from first appearance of surface effects, Camera D-3A.

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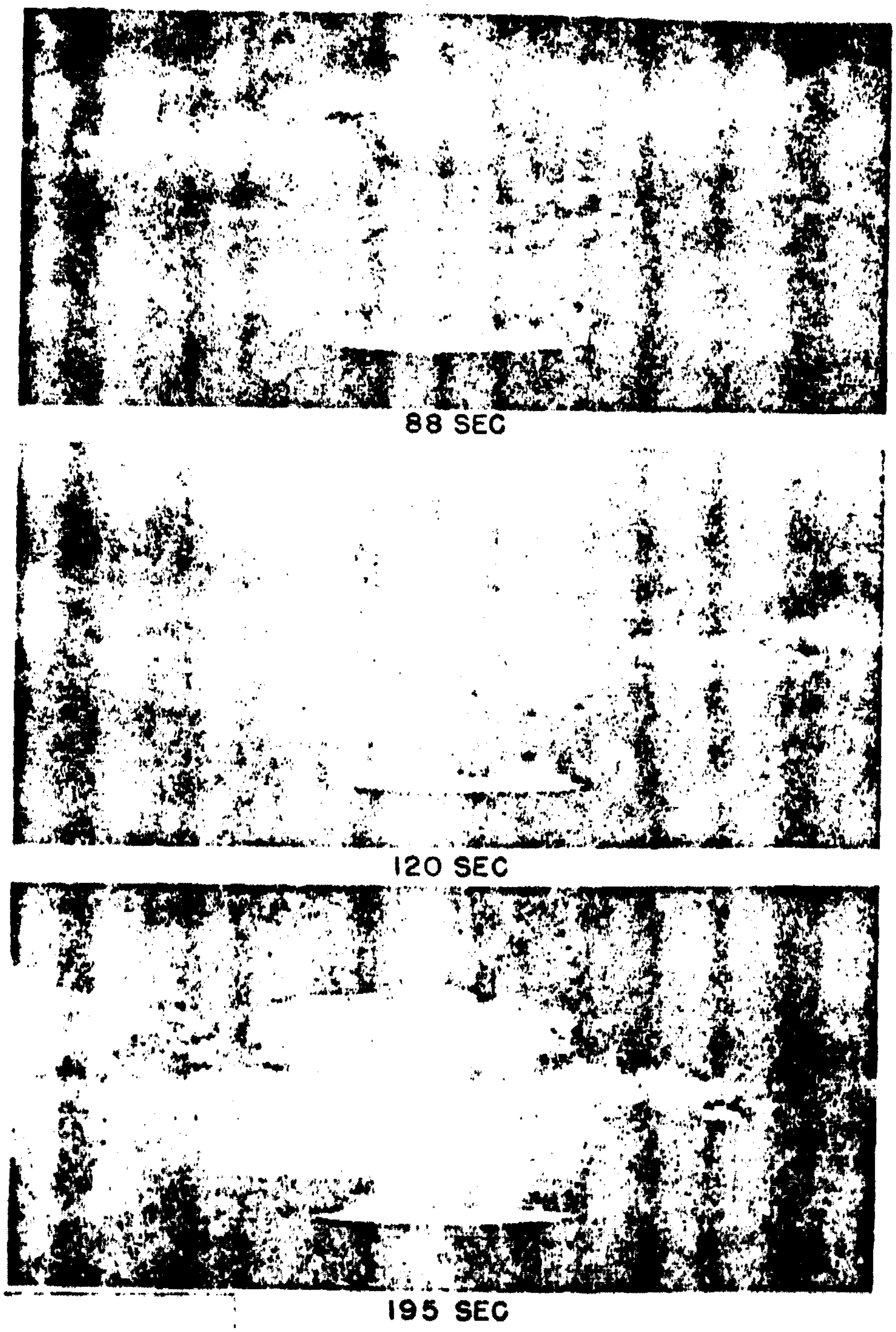

Fig. 3.33—Base surge at late times. Times are measured from first appearance of surface effects. Camera H-3.

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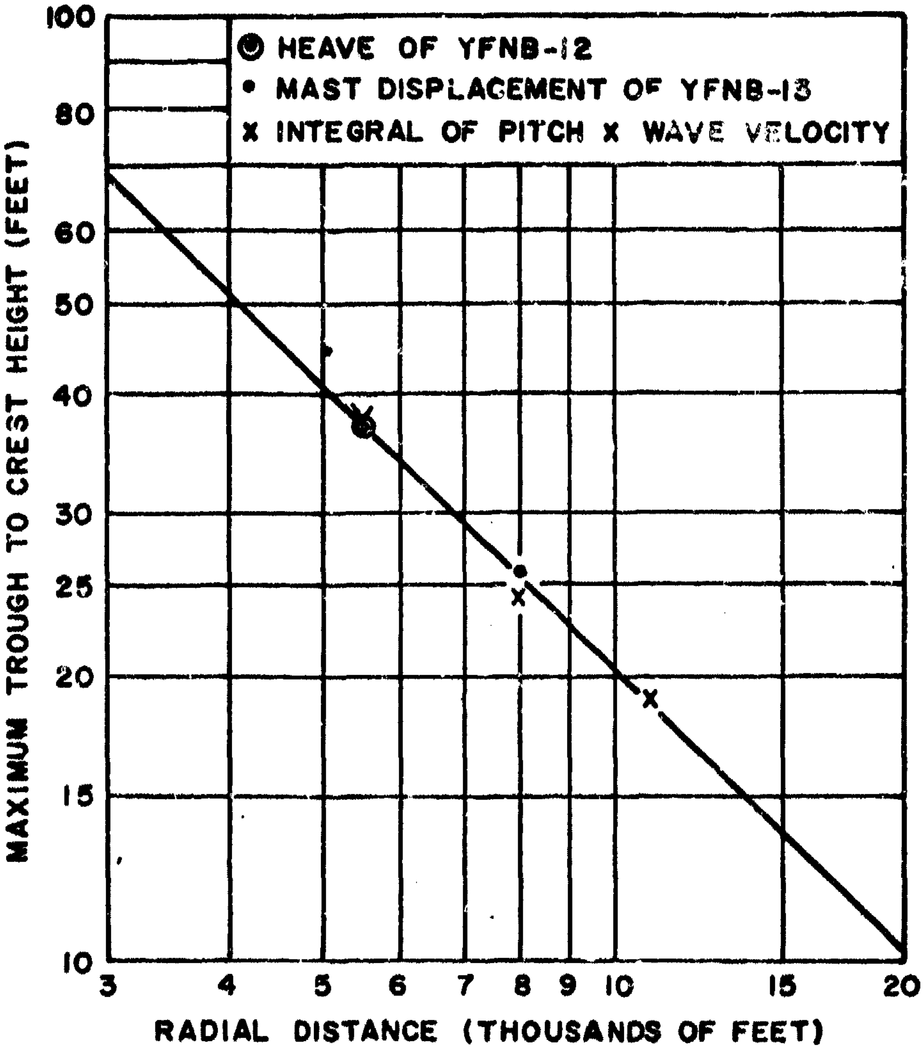
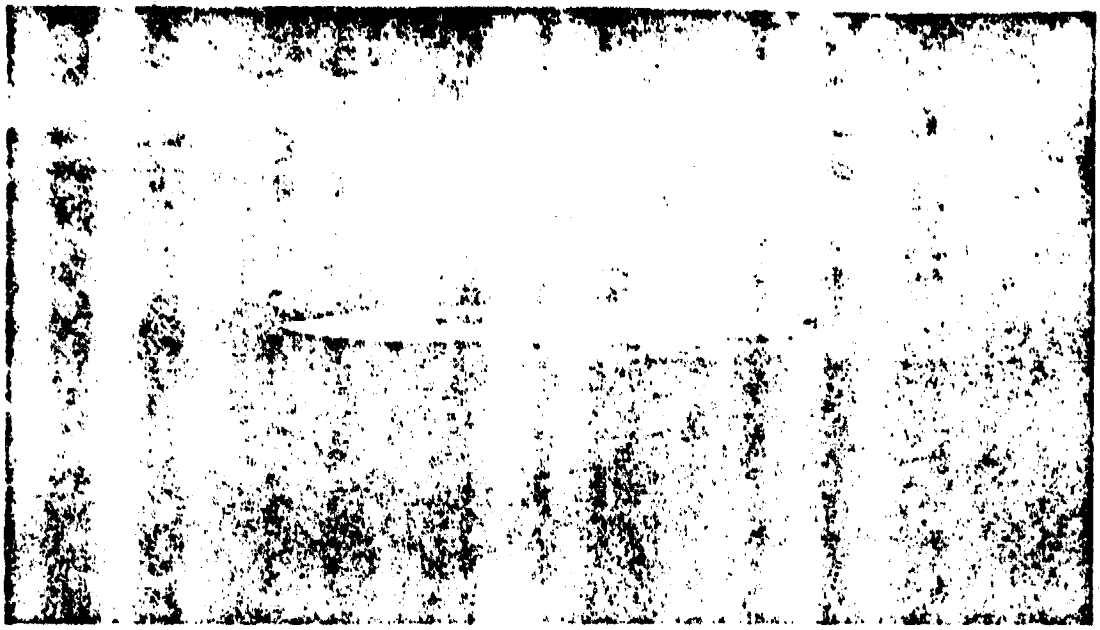
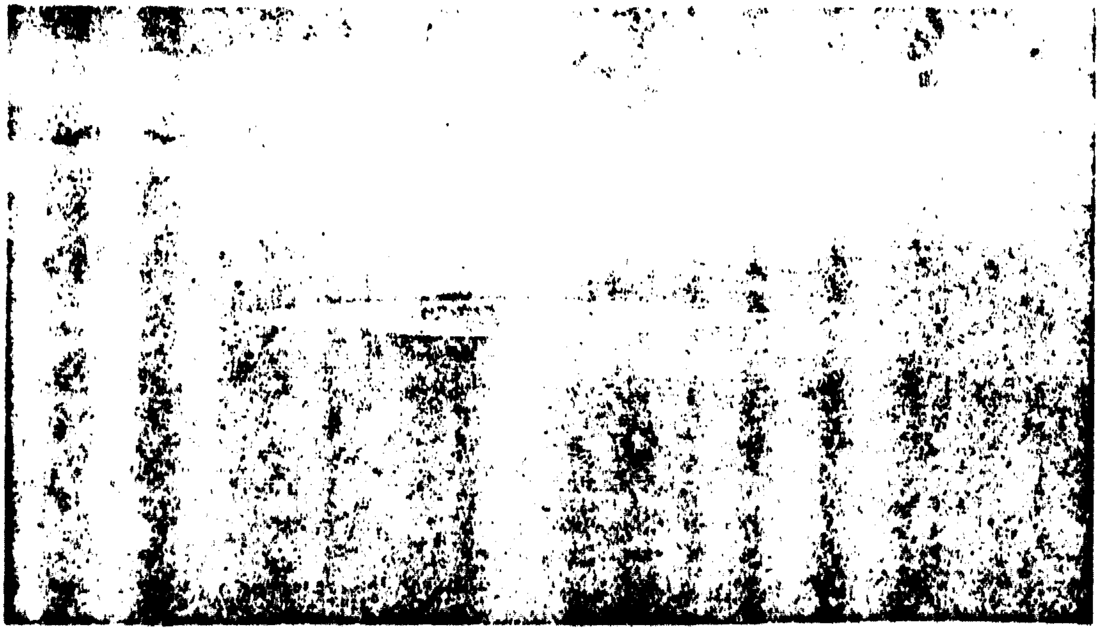


Fig. 3.34—Maximum wave height vs radial distance.



6.5 MIN



10.5 MIN

Fig. 3.35—Foam ring. Camera J-3.

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2. Results

Although equipment installed on the YFNB-12 appeared to operate satisfactorily, no useful record was obtained. This failure could indicate either (a) that no illumination above background was received at a depth of 1000 ft, 5500 ft from Surface Zero, or (b) that the equipment was not functioning. A choice between these alternatives is not possible.

3. Recommendation

Further improvement of equipment and its use on future operations is desirable.

PROJECT 2.1

TITLE: Collection of Early Water Samples for Radiochemical Analysis and Yield Determination (Operation Wigwam, WT-1039, Confidential-RD, Dr. William G. Van Dorn)

PROJECT OFFICER: Dr. William G. Van Dorn

ORGANIZATION: Scripps Institution of Oceanography, University of California, La Jolla, Calif.

1. Objectives

a. Supply other agencies with sea-water samples from the surface and just below the thermocline (400 ft) taken as early after shot time as possible.

b. Make an air-borne water-surface temperature survey in conjunction with an air-borne radiological survey by Project 2.4 with a view to making an early forecast of hydrodynamic and radiological conditions.

c. Establish a floating range of drogued buoys across the shot site.

d. Cooperate with Scripps Institution of Oceanography surface vessels in a long-term (3 to 4 days) survey of the distribution of radioactivity in the water.

2. Results

Project 2.1 provided essentially a support function for Operation Wigwam.

Surface and thermocline-depth water samplers were air-dropped across the shot site within 21 min after shot time, and radioactively self-tripping samplers were towed through the area within 1 hr, but delayed entry by recovery crews and the sinking of samplers due to vortex motion in the water largely vitiated the proposed objective of furnishing early, radioactive water samples to agencies interested in weapon-yield analysis.

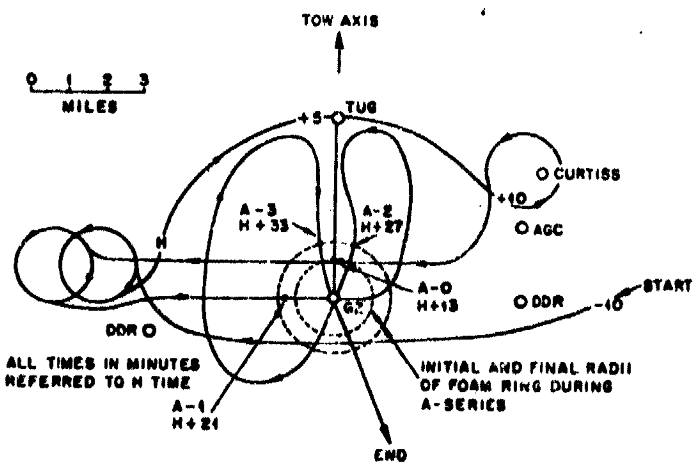


Fig. 2.36—Survey-aircraft flight plan for Able-series passes across Surface Zero.

An attempt to mark the shot area by laying a line of floating range buoys equipped with parachute drogues across Surface Zero was unsuccessful for the same reasons.

A joint aerial survey of the area (with Project 2.4) aimed at forecasting and documenting the early radiological and hydrodynamical situation in the water after the shot was successful (Fig. 3.36). An interpretation of the water motion for the first 2 hr, as deduced from visual evidence, was made.

3. Recommendations

Future operations should not be planned just to the shot time. Granted that phenomena are not always predictable, a plan or several alternate plans should be ready for execution as soon as the shot occurs.

Since division of responsibility in sampling, sample collection, and processing was extremely unsatisfactory, single-agency responsibility for the whole process is recommended. If this cannot be realized, then assignment of the responsibility for continuity to one individual should be made.

The drogue-buoy sampling system should be completely reevaluated.

PROJECT 2.2

TITLE: Radiochemical Analysis of Wigwam Debris (Operation Wigwam, WT-1010, Secret-RD, Dr. Luther B. Lockhart, Jr., and Richard A. Baus)

PROJECT OFFICER: Dr. Luther B. Lockhart, Jr.

ORGANIZATION: U. S. Naval Research Laboratory, Washington, D. C.

1. Objective

Determine the effect of high pressures and confining environment of a deep underwater explosion of an atomic device on such factors as yield, efficiency, induced activities, fission-yield ratios, fractionation, and the like.

2. Results

Fission-yield Ratios: The results of the radiochemical analysis of the four available samples for certain fission products are reported in Table 3.1.

PROJECT 2.3

TITLE: Radiochemical and Physical Chemical Properties of Products of a Deep Underwater Nuclear Detonation (Operation Wigwam, WT-1011, Secret-RD, Dr. N. E. Ballou)

PROJECT OFFICER: Dr. N. E. Ballou

ORGANIZATION: Chemical Technology Division, U. S. Naval Radiological Defense Laboratory, San Francisco, Calif.

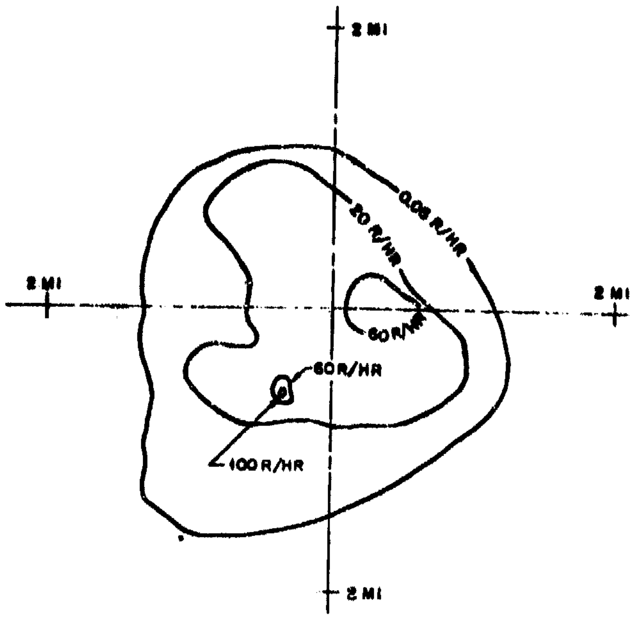


Fig. 3.37—Radiation contours at H + 0.33 hr.

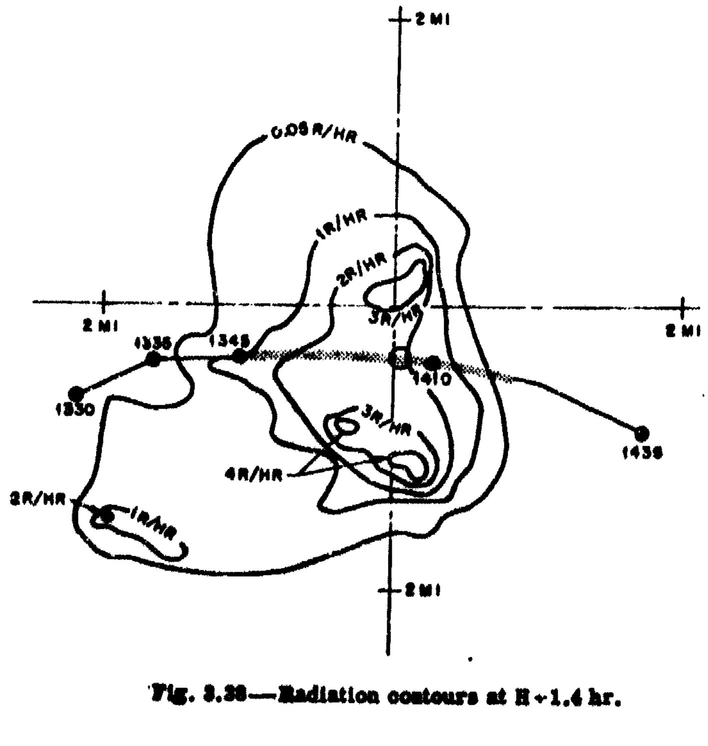


Fig. 3.38—Radiation contours at H + 1.4 hr.

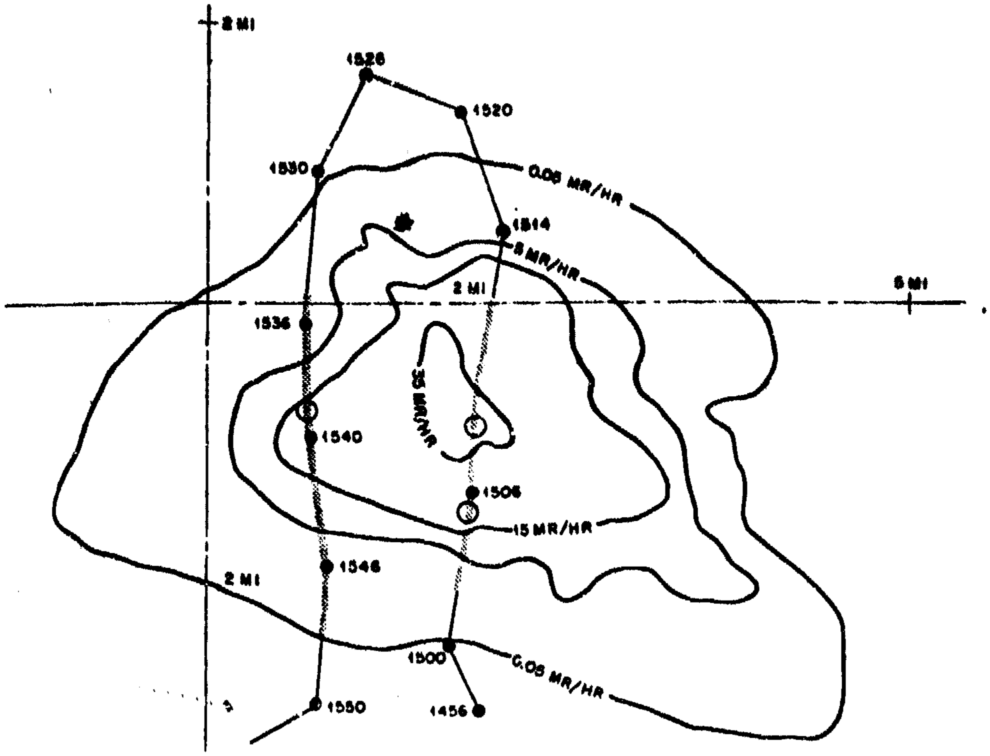


Fig. 3.39—Radiation contours at H + 26 hr.

1. Objectives

Make the following determinations from samples of surface water, deep water, and airborne material:

a. Total beta and gamma activity.

b. Radiochemical composition.

c. Concentration of main weapon components.

d. Distribution of activity between solid, colloidal, and ionic phases and radiochemical composition of each phase.

e. Valence state of selected radionuclides.

3. Recommendations

a. That the techniques used in this project be fully exploited in future tests.

b. That preparation for future tests include a concentrated effort toward the development of better sample-collection methods.

c. That future test operation plans include carefully rehearsed and coordinated sample-recovery schemes in which personnel safety is the only superseding factor.

PROJECT 2.4

TITLE: Determination of Radiological Hazard to Personnel (Operation Wigwam, WT-1012, Official Use Only, M. B. Hawkins, J. D. Sartor, J. E. Howell, M. M. Bigger, W. S. Kehrer, F. K. Kawahara, F. S. Vine, Hong Lee, R. H. Black, R. J. Crew, W. B. Lane, and R. R. Soule, U. S. Naval Radiological Defense Laboratory, and R. Graveson, New York Operations Office, Atomic Energy Commission)

PROJECT OFFICER: M. B. Hawkins

ORGANIZATION: U. S. Naval Radiological Defense Laboratory, San Francisco, Calif.

1. Objectives

Experimental: Determine radiological hazard to personnel aboard ships traversing a zone of water contaminated by a deep submerged atomic burst by measuring:

a. The size, shape, location, and radiation characteristics of the radioactively contaminated area as a function of time.

b. The gamma-radiation intensity at specific stations throughout a ship during and subsequent to traverses through the area.

c. The extent of residual contamination on the hull and exposed surfaces of the ships; the performance of the washdown system; and the effectiveness of various contamination countermeasures.

Operational: Provide to the task group commander, his assistants, and/or project and program leaders:

a. Surface-phenomena and radiological information from early times.

b. Surface and shallow-depth water samples.

c. Facilities, logistic support, and coordination through the Program II Plot and/or use of Project 2.4 ships and aircraft.

d. General assistance, information, and manpower when feasible.

2. Results

Aerial Survey: An aerial survey was found to be an effective method of obtaining radiation-intensity information as well as a rough outline and location of a contaminated area at any time after an underwater nuclear detonation within the limits of the detection instruments and radar-equipment tracking range.

Detonating conditions of the weapon at Operation Wigwam produced several radiological environments: (a) a contaminated water area due to the debris thrown out with the surface effects or upwelling of contaminated water from below, (b) a downwind "cloud" of air-borne radioactive material, and (c) the residual "fall-out" from the cloud.

At the time of initial measurement (H + 19 min) the contaminated water area was about 5.3 sq miles and about $2\frac{1}{2}$ miles in diameter (Fig. 3.40). The area was contaminated in an irregular manner, the peak intensities being approximately three times the average intensity.

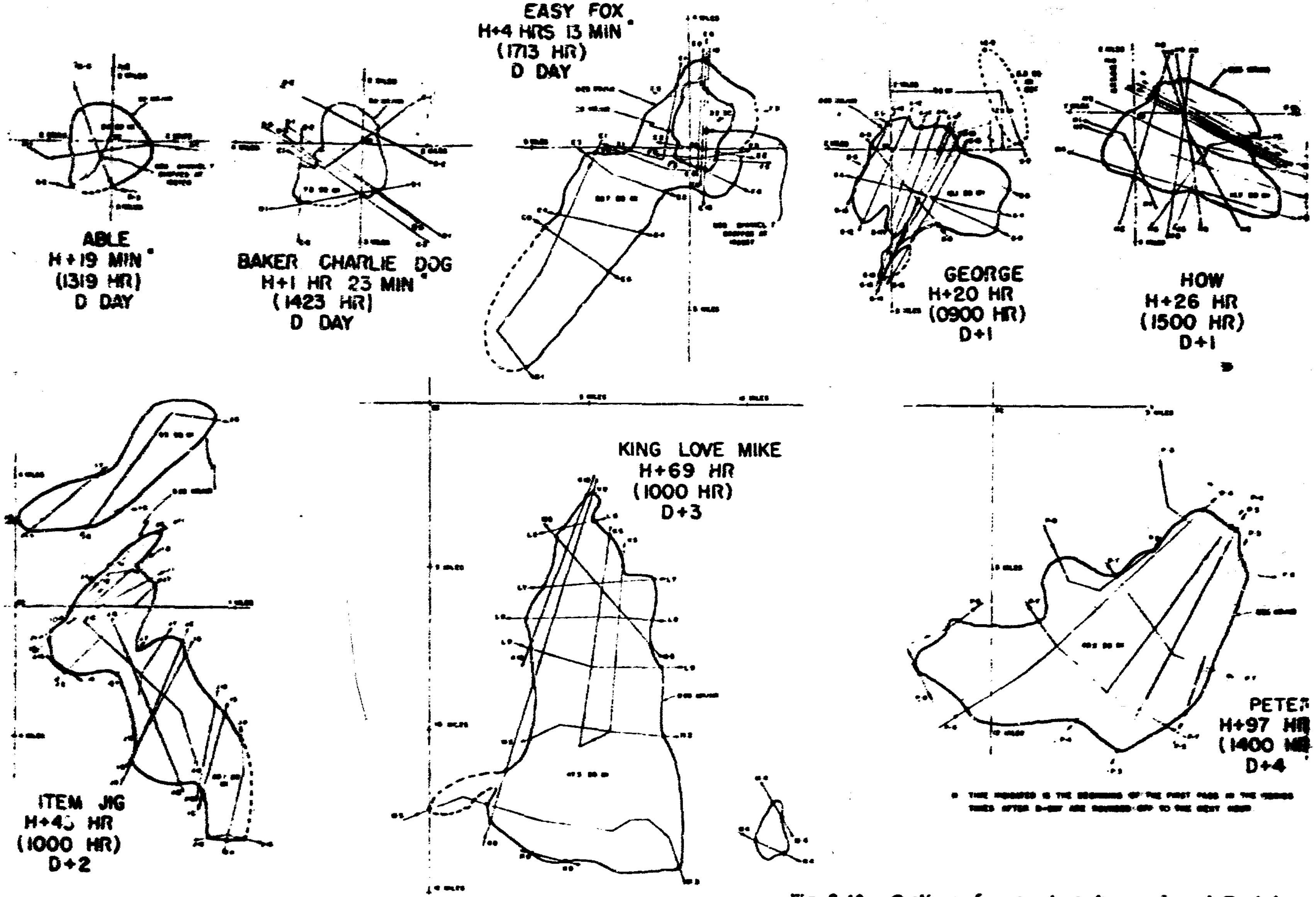


Fig. 3.40—Outlines of contaminated areas through D+4 days

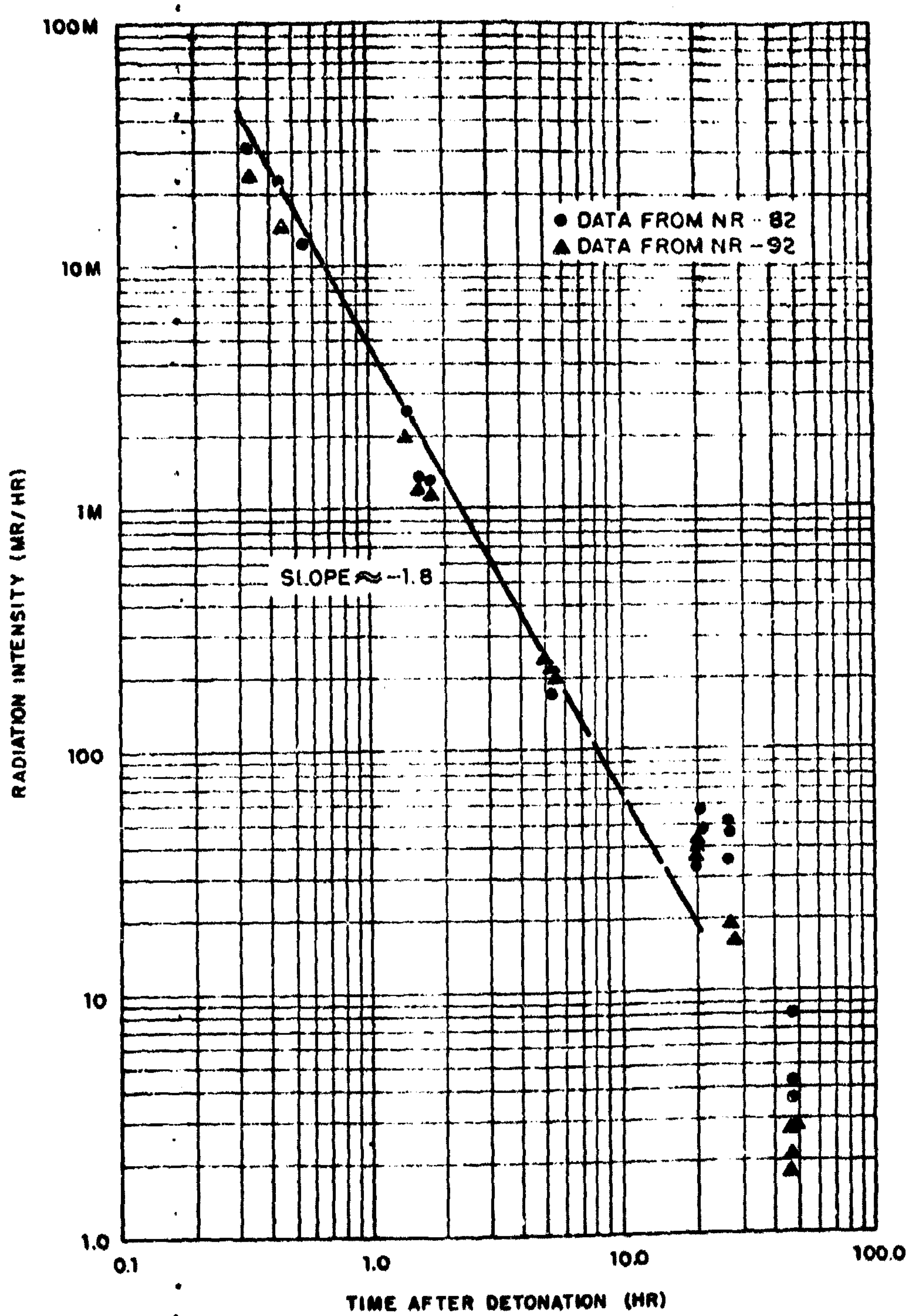


Fig. 3.41 — Average radiation intensity 3 ft above surface.

The average transit intensity across the area was about 25 to 30 r/hr 3 ft above the surface (Fig. 3.41).

The radiation intensity decreased at a rate represented by the exponent −1.8. Separate measurements indicated an actual radioactive decay exponent of −1.5.

The area circumscribed by a 50 mr/hr isointensity contour increased to 7.5 sq miles at H + 1.4 hr. At H + 4.2 hr it had decreased to 3.5 sq miles. Average transit intensities at these times were about 2 to 3 r/hr and 300 to 400 mr/hr, respectively.

Assuming that the decay exponent −1.8 held at early times, the average transit intensity was about 3000 r/hr at H + 2 min.

Ship Hazard and Countermeasure Studies: The over-all experiment was completed as planned except for deviations caused by the low initial levels in the radioactive sea water (Fig. 3.42). The third decontamination series was not accomplished because of decay.

The relative effectiveness of the four decontamination methods and the three liquid decontaminants was clearly demonstrated.

It was shown that, in general, galvanized iron is much more difficult to decontaminate than Navy gray paint.

A comparison of the decay curves (Fig. 3.43) for gross gamma in the radioactive sea water and the gamma from the liquid aerosol shows that no measurable fractionation occurred during aspiration.

A comparison of decontamination measured by gamma counting with that measured by chloride analysis shows that the radionuclides do not necessarily follow the salt deposit in decontamination procedures but may adhere to the painted and galvanized surfaces while the chloride is desorbed or dissolved.

Water Sampling and Analysis: Within the sensitivity of the recording system, there was no discernible temperature difference between contaminated and uncontaminated areas.

Figure 3.44 shows the gamma decay of the radioactive material in the water, as determined by the equipment in the low-background room. As indicated, the exponent n in the relation $A/A_0 = t^{-n}/t_0$ was found to be approximately 1.5 from 1 to 10 hr and 1.2 from 10 to 100 hr after detonation.

The gamma decay exponent as derived was about 1.5 from 1 to 10 hr and 1.2 thereafter.

3. Recommendations

a. That much more complete fall-out, shielding, washdown, and decontamination experiments be performed in future tests.

b. That concentrated effort be devoted to developing better sampling and survey methods. This effort should include design of improved sample-collecting vessels and use of fire-control radar systems for fixing the location of survey aircraft.

c. That good field equipment be developed for gamma-spectrum analysis.

d. That the radiac system be reevaluated and possibly replaced with more powerful and reliable equipment.

PROJECT 2.5

TITLE: Effects of Nuclear Explosion on Marine Biology (Operation Wigwam, WT-1013, Official Use Only, Dr. M. B. Schaefer)

PROJECT OFFICER: Dr. M. B. Schaefer

ORGANIZATION: Scripps Institution of Oceanography, University of California, La Jolla, Calif.

1. Objectives

a. Study the distribution of marine organisms in and near the proposed test area to provide information which, together with data from Project 2.8 on currents, would make possible selection of a test site such that the hazard to the fisheries would be minimal.

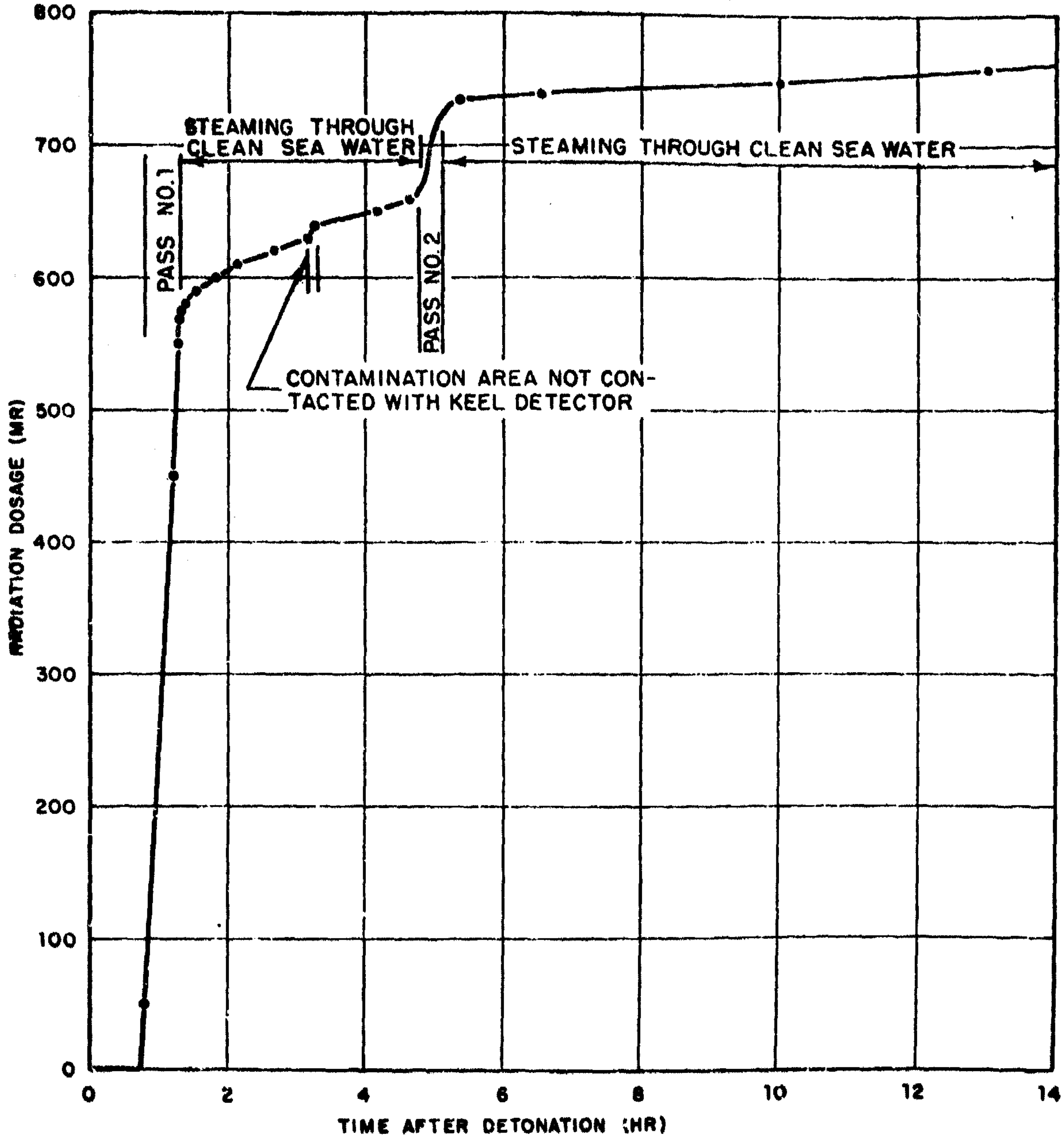


Fig. 3.42—Accumulated radiation dosage at Station 27, in Hold No. 2, of the YAG-40.

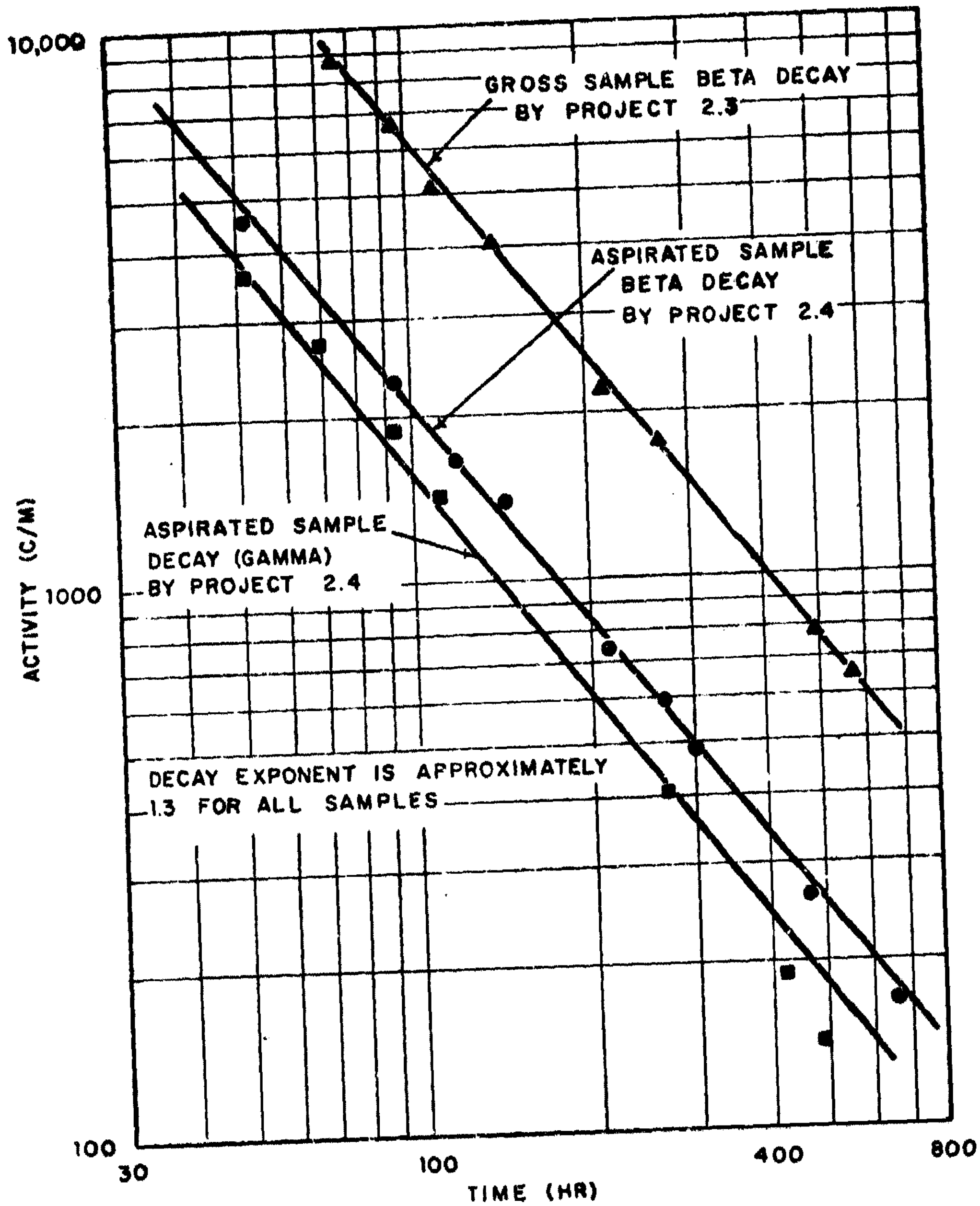


Fig. 3.43—Decay comparisons.

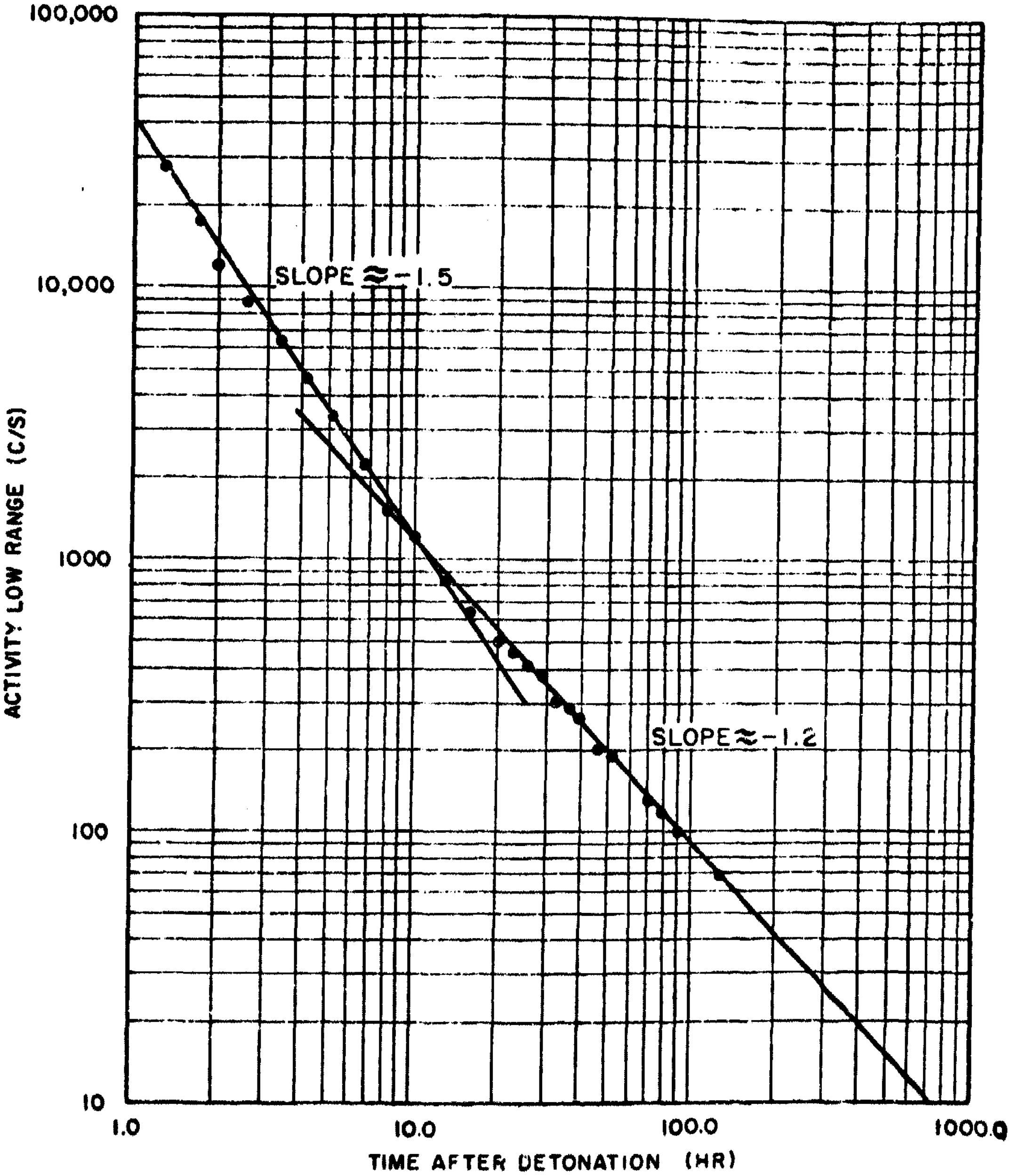


Fig. 3.44—Gamma decay of sea water.

b. Make laboratory studies on the uptake of fission products by fishes and other marine organisms to learn about the uptake of such products from sea water and their retention and excretion by the organisms.

c. Make field studies following the test to investigate the uptake of resulting fission products by marine organisms.

2. Results

It was shown that, except in the portions of the area immediately adjacent to the coast, the region is low in phytoplankton, zooplankton, forage fishes, and large pelagic fishes. The northwestern part of the region of study, in the vicinity of 123°W, 28°N, was particularly barren.

Long-line fishing in the vicinity of the test site, just prior to and after the test, confirmed the absence of significant numbers of tunas or other large pelagic commercial fishes in the area at the time of the test.

Experiments were conducted on the uptake of Sr^{90} and Y^{90} by *Serratia marinorubra* and *Platymonas subcordiformis* in radioactive media. *Serratia marinorubra* was shown to be able to concentrate the activity from 6000 to 25,000 times. Of the activity retained, 95 per cent was due to Y^{90} and 4 per cent to Sr^{90}. On the basis of atom uptake, more Sr^{90}, approximately 130 times as much, was found. The percentage values for concentration of atoms showed a greater concentration for Y^{90} than Sr^{90}, presumably because of the 3592 : 1 ratio of Sr^{90} and Y^{90} in the medium initially. *Platymonas subcordiformis* selectively concentrated Y^{90} more than Sr^{90}. On a percentage atom uptake basis, Y^{90} was concentrated to a greater degree than Sr^{90}.

Experiments by feeding microorganisms, which had taken up Sr^{90}-Y^{90}, to a copepod were conducted to determine the rate of feeding of the copepod and the transfer of activity up this step in the food chain. Results were not conclusive.

Experiments were conducted to determine the amount of radioactivity taken up by laboratory cultures of marine dinoflagellate *Gonyaulax polyedra* from sea water containing mixed fission products collected in the Wigwam test area. A concentration of activity in the cells of this organism of about 5000 times in a period of 90 hr was indicated. From concentration factors in different dilutions of radioactive sea water, it appears that in the range of 5 to 50 per cent dilution, the concentration factor is independent of dilution. Studies of energy spectra of the cells which had taken up activity suggest differential uptake of certain energies. The corresponding isotopes were not identified.

The evaluation of potential uptake of fission products, and potential sites of concentration of various elements, was undertaken by studying the elemental composition of various organs of tunas and other pelagic fishes.

The data indicate that the elements existing most probably as cationic species in sea water (Mn, Cu, Ni, Zn, etc.) tend to be concentrated in the internal organs. The alkaline earths (Ca and Sr) concentrate in the hard parts, and Sr appears more strongly in the flesh than Ca. Most Sr is found in the internal organs and least in the hard parts.

Studies of uptake, retention, excretion, and sites of deposition of Sr^{90} in a representative pelagic food fish, the Pacific mackerel *(Pneumatophorus diego)*, were undertaken by feeding this isotope and studying total activity and its distribution in various organs after various periods of time up to 235 days. It was found that 95 per cent of the activity was excreted in 24 hr but that the remaining 5 per cent remained fixed in the body for the duration of the experiment. Of this fixed activity, 80 per cent was located in the skeletal structures. The edible portion of the fish showed, per gram, low activity after two days. After one to three days after feeding, the gills showed the highest activity per unit weight, suggesting them as the site of major excretion.

Radiochemical studies of sea water, of the particulate matter in the sea water, and of the organisms were made on the basis of samples collected at the test site during the first few days after the shot. Approximately half the activity in the sea water was found to be due to materials present in particulate form.

The most active organisms during this early time, and hence the most effective concentrations of activity, were mucous, pseudopodal, ciliary-feeding zooplankton species which, it is presumed, were ingesting the particulate matter. Limited assays of diatoms indicated low

effectiveness in accumulating activity, although this result is somewhat doubtful due to possible faulty technique.

During this early period the fishes showed no significant concentrations of activity except in the stomach and gut regions, indicating that they were feeding on organisms lower in the food chain which were radioactive but that the active elements had not yet reached deposition sites in the other parts of the fish. No long-term studies for sites of accumulation of specific isotopes were conducted.

3. Recommendations

a. That a thorough study be made of elemental composition of pelagic fishes.

b. That in future operations vessels be assigned with the primary mission of surveying fission-product distribution between marine water and members of the biosphere by collecting sufficient and properly located samples.

c. That the laboratory techniques developed for isotope uptake and retention be used for future and more extensive investigations.

d. That practical and reliable shipboard laboratory techniques be developed.

e. That long-term studies of sites of accumulation for specific isotopes be conducted.

PROJECT 2.6 (Part I)

TITLE: Mechanism and Extent of the Dispersion of Radioactive Products in Water (Operation Wigwam, WT-1014, Secret-RD, J. D. Isaacs)

PROJECT OFFICER: J. D. Isaacs

ORGANIZATION: Scripps Institution of Oceanography, University of California, La Jolla, Calif.

1. Objectives

Determine: (a) the nature of the circulation induced by the Wigwam test and (b) the early distribution of fission products.

2. Results

The principal bodies of radioactive water were located and surveyed. Temperature and current measurements were made. The principal findings of the survey were as follows:

a. Approximately one-third of the radioactivity remained in the surface layers and approximately two-thirds of the activity subsided to (or remained at) depths well below the thermocline (Figs. 3.45 and 3.46).

b. At no time after the event was water found that had been heated significantly by the explosion.

c. Surface contamination was relatively well mixed with water in the surface layer, except for a small isolated body of contaminated water just above the thermocline.

d. Deep contaminated water was relatively unmixed and consisted of a series of thin laminae in complex configuration and motion. Figure 3.47 shows a time series of depth profiles from a slowly drifting ship.

e. The most highly contaminated water found was in the deep laminae.

f. The total radioactivity surveyed was 8.5×10^7 curies calculated at 120 hr. The predicted quantity was 8.41×10^7 curies at 120 hr.

3. Conclusions

a. All principal masses of contaminated water were discovered and adequately surveyed. The close agreement between the total activity surveyed and the predicted quantity is accidental.

b. The intensely radioactive water welled to the surface at early times and subsided to its equilibrium depth of 200 to 300 meters. The water originated from somewhat deeper than this

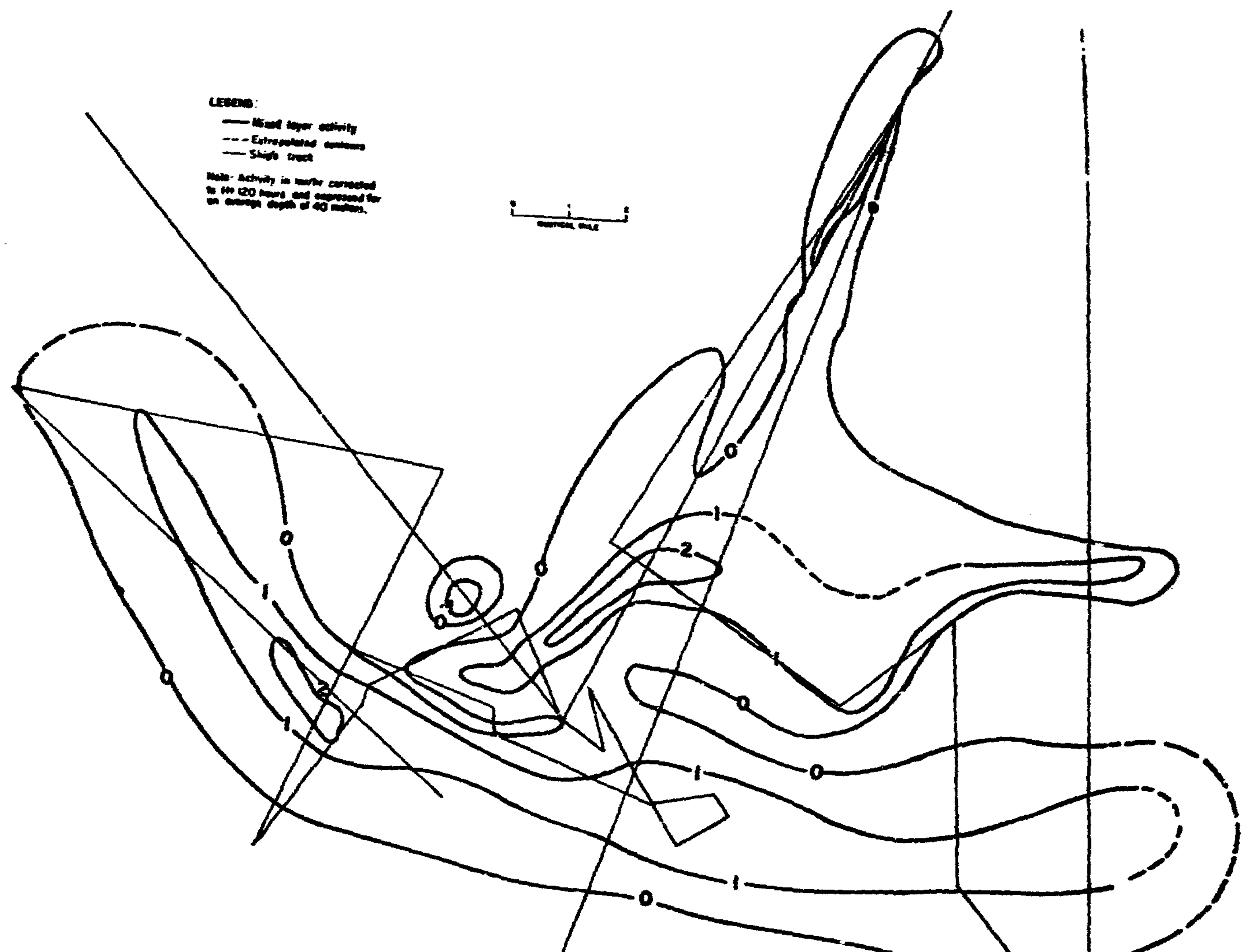


Fig. 3.45—Contours of activity. Surface survey of 21 and 22 May 1955, corrected for current.

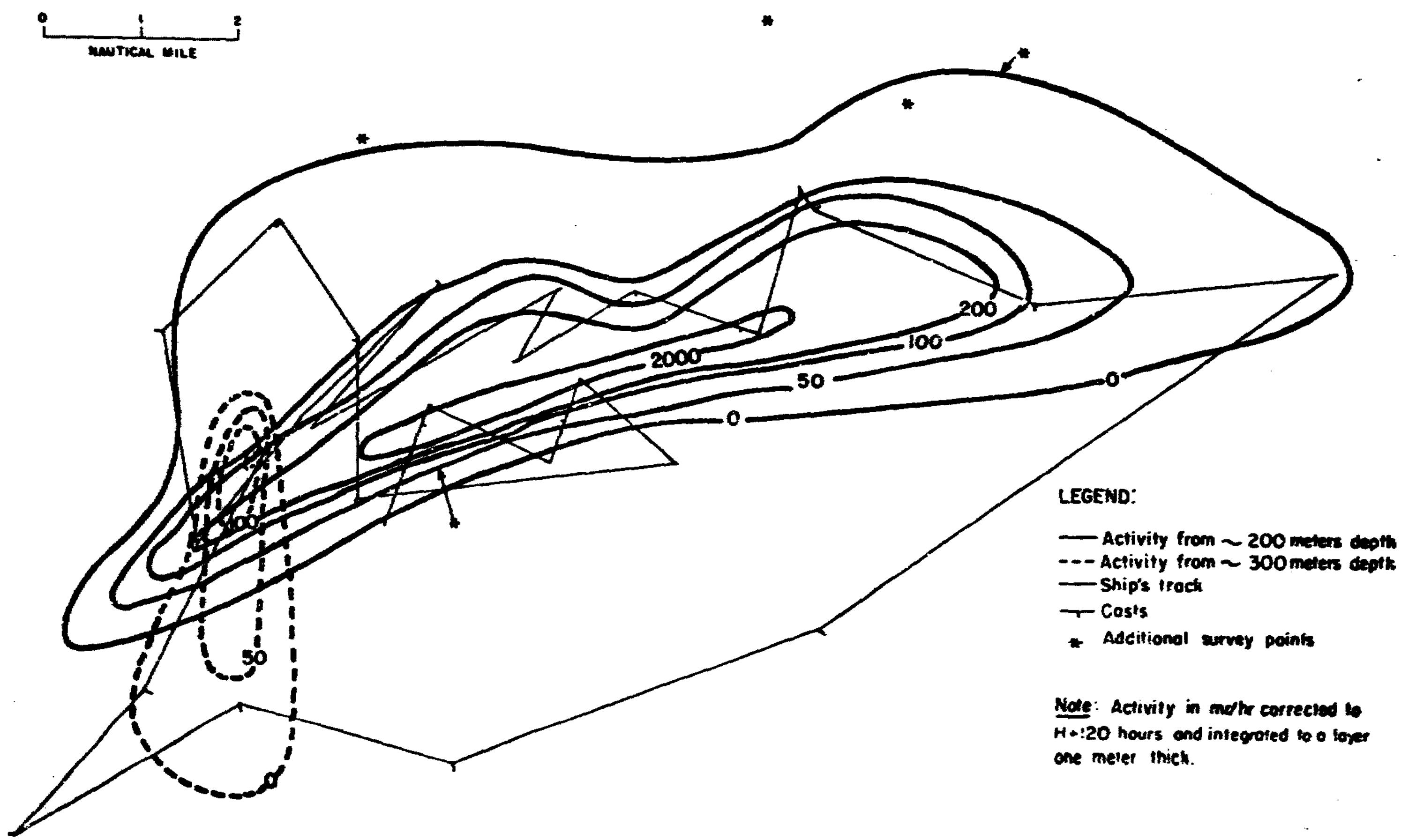


Fig. 3.46—Contours of integrated activity. Deep survey of 17 and 18 May 1955, corrected for current.

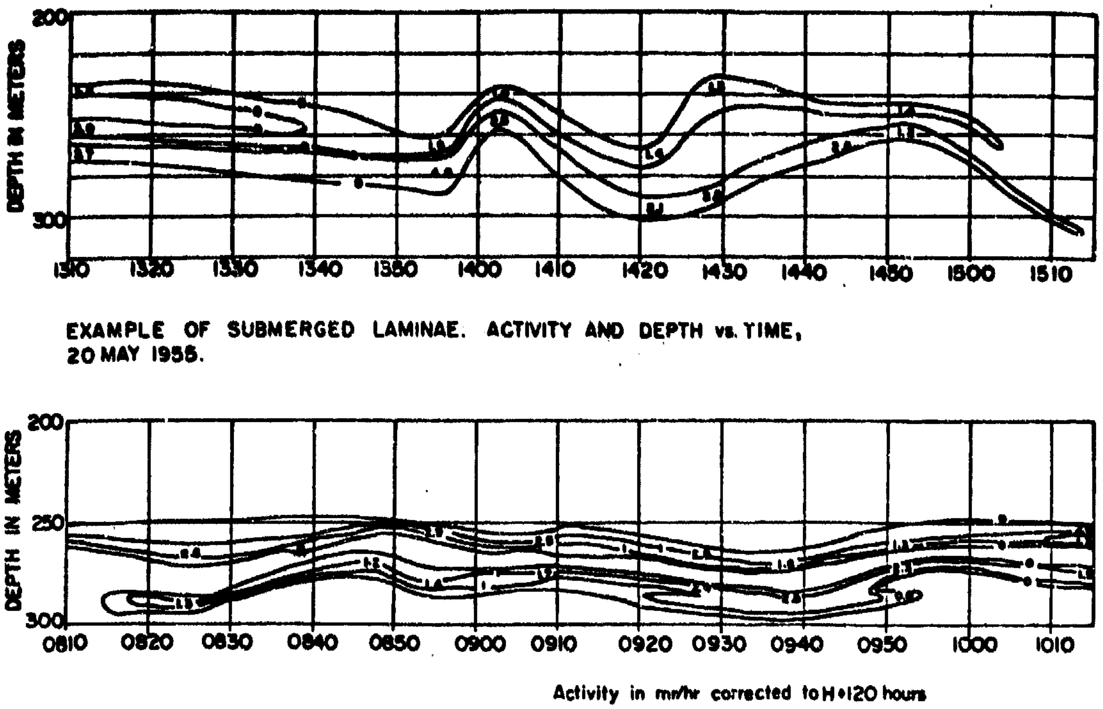


Fig. 3.47—Examples of submerged laminae.

equilibrium depth and was mixed with surface water before subsiding. This mixing was responsible for the warming of the water.

c. The thermal structure of the water column exerts the greatest influence on the distribution of radioactivity. It is probable that, in cases of detonations at a depth where the water temperature is closer to that of the surface layers, the highly contaminated water will remain stably on the surface. Such water would result in a radiative intensity at the surface of not less than 400 r/hr at 30 min.

PROJECT 2.6 (Part II)

TITLE: Mechanism and Extent of the Dispersion of Fission Products by Oceanographic Processes and Locating and Measuring Surface and Underwater Radioactive Contamination (Operation Wigwam, WT-1015, Confidential-RD, Dr. Theodore R. Folsom)

PROJECT OFFICER: Dr. Theodore R. Folsom

ORGANIZATION: Scripps Institution of Oceanography, University of California, La Jolla, Calif.

1. Objective

Track the water-borne fission products and determine the extent of their dispersion through oceanographic processes until radiation levels approach background.

2. Results

Vertical Distribution: At the end of 40 days, contaminated water was found which showed activity mixed fairly uniformly to a depth of 40 to 60 meters, where the first small thermal discontinuity was found, although the depth of the thermocline was about 160 meters (Fig. 3.48).

Horizontal Distribution: On 19 June 1955, 37 days after the detonation, the contaminated water mass was found to be 120 miles west of Surface Zero and to be distributed as shown in

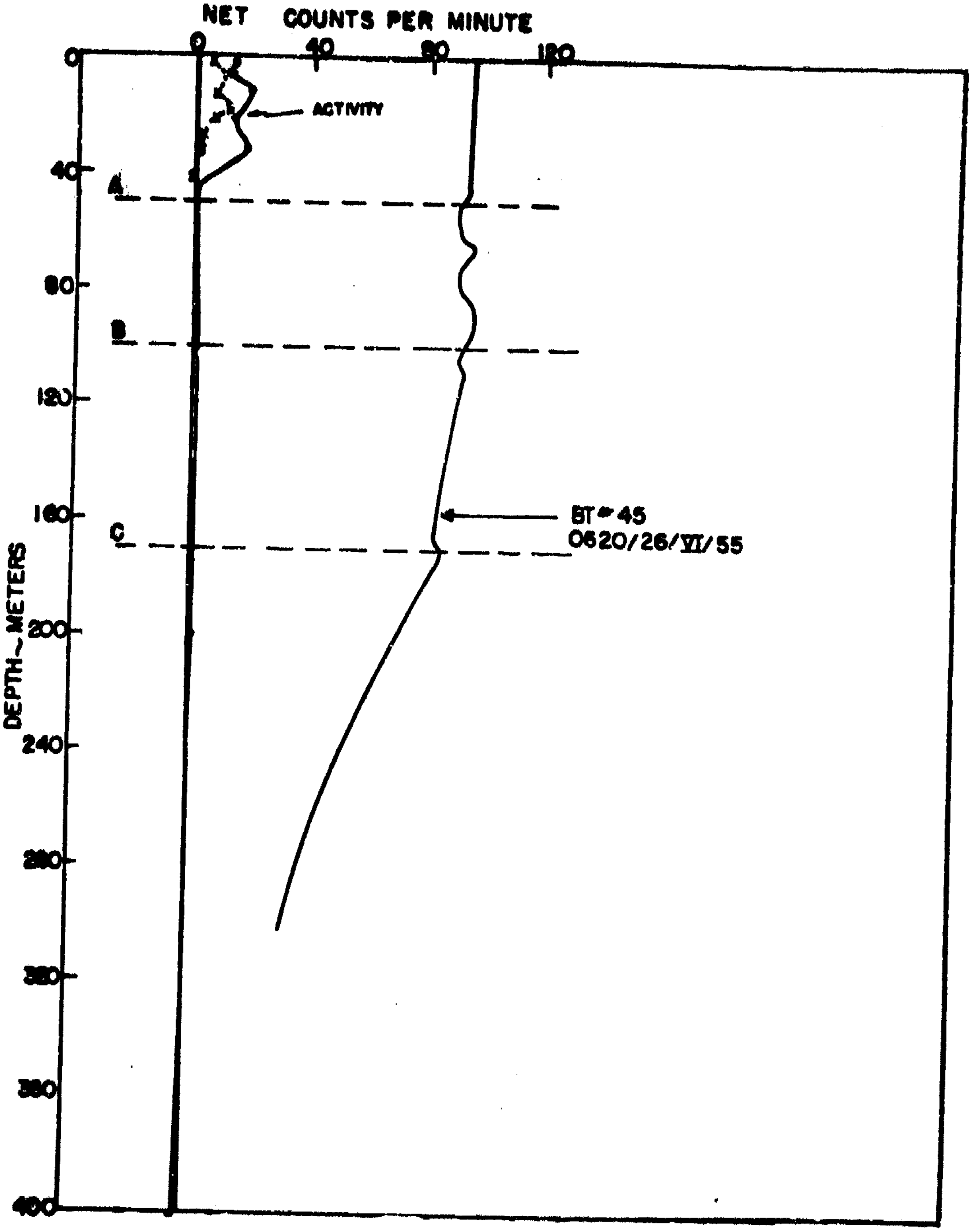


Fig. 3.48—Activity contour compared with thermal contour at Station B-19 from 0515 to 0700 on 26 June 1955.

Fig. 3.49. It appears that at H + 612 hr, 3×10^6 curies of fission products remained in the upper layers of the sea.

3. Recommendation

A more continuous surveillance of the contaminated water mass is required to provide information leading to the determination of the mechanisms causing the observed dispersion.

PROJECT 2.6 (Part III)

TITLE: Radiological Techniques and Instruments Used for the Oceanographic Survey on Operation Wigwam (Operation Wigwam, WT-1016, Unclassified, Dr. Theodore R. Folsom)

PROJECT OFFICER: Dr. Theodore R. Folsom

ORGANIZATION: Scripps Institution of Oceanography, University of California, La Jolla, Calif.

1. Objective

Develop and provide instruments and techniques to be used in surveying the water affected by the detonation of nuclear weapons.

2. Results

Presence of fission products in the water was detected by the gamma rays emitted. Halogen type Geiger tubes were chosen as detectors because of their simplicity and reliability, and means were devised for permitting the combined use of several sizes of these tubes so that gamma-ray intensities could be measured over a long range.

A pressure-resistant watertight shell necessary for work below the sea surface was developed. It was designed toward maximum ease of handling on deck, and toward simplicity, robustness, and low cost. Constructional features, including a scheme for interchanging internal components to modify the instrument's sensitivity, are shown in Fig. 3.50. The instrument calibrations are shown in Fig. 3.51.

The operational procedures which were used on Operation Wigwam permitted probing of water masses vertically and sweeping through them horizontally.

Methods were improved for securing water samples out of thinly stratified laminae several hundred meters below the surface.

A water-sampling device was designed and constructed at Scripps Institution of Oceanography for being towed behind the NRDL ship, which was expected to make the first entry into the target area (Fig. 3.52). Gamma contamination should automatically release a mechanism sealing off a water sample. Unfortunately, it appears that the samplers did not enter sufficiently active water, and therefore they collected no sample.

Several techniques for recording the gamma intensity above the sea surface were used. One device, called a "NAVRAD," was successfully used to inform the helmsman immediately of the radioactive condition of the surface water. It also indicated when intensely radioactive water was approached and on which quarter it was to be found.

A cheap device used for warning those engaged in recovery activities of deep-lying hazardous water was developed.

3. Recommendations

Although the instruments were largely satisfactory, they should be modified to provide simplicity and ruggedness for use on naval operations, greater sensitivity for surveying small traces of contamination of interest as hazards to humans, and improved efficiency in mapping oceanographic phenomena.

PROJECT 2.7

TITLE: Fall-out and Air-borne Activity in Operation Wigwam, with Notes on Surface Effects (Operation Wigwam, WT-1017, Confidential-RD, Frederic A. French)

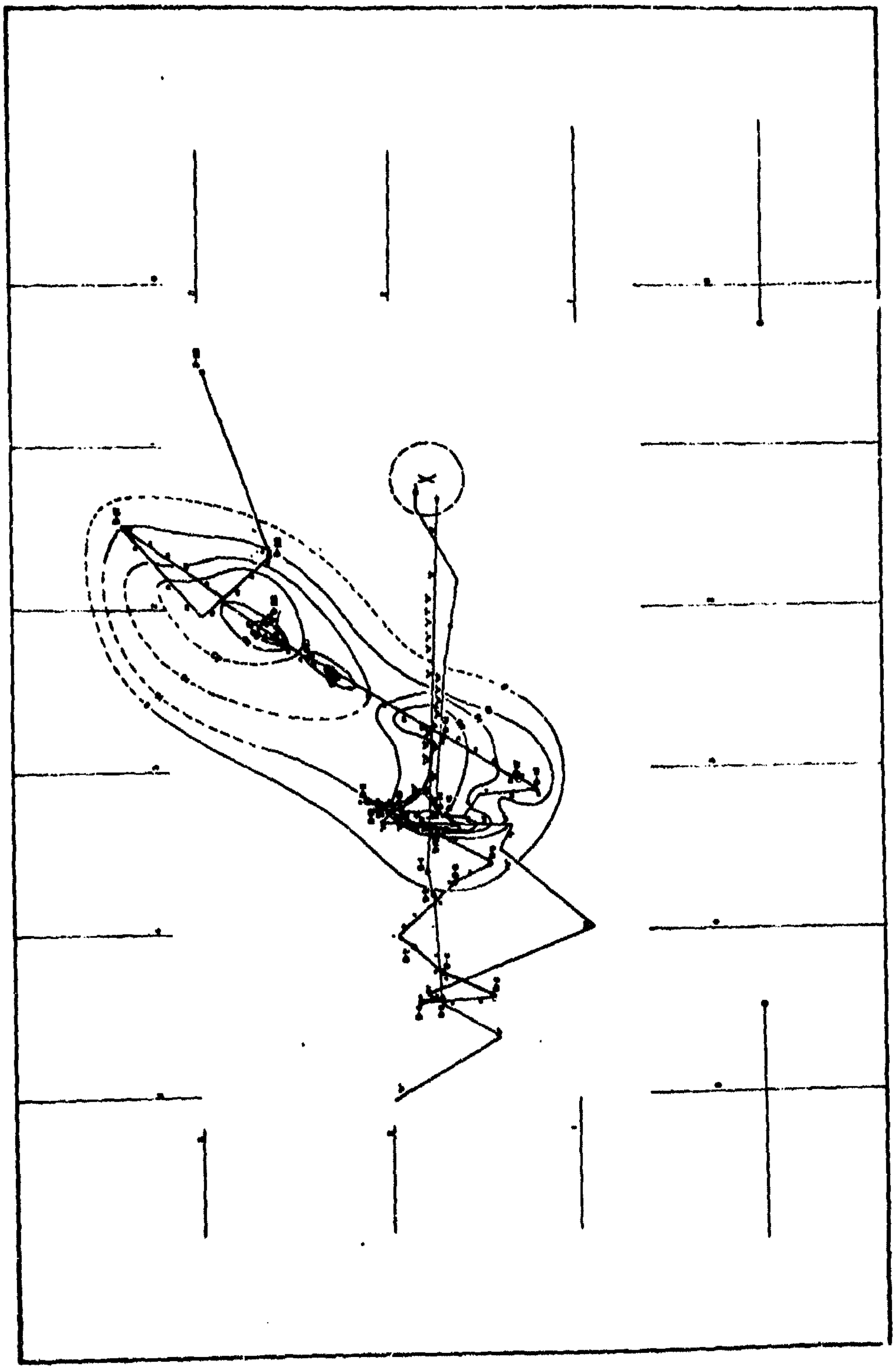


Fig. 3.49—Synoptic contours of approximate activity (see Table 3.1 of WT-1015).

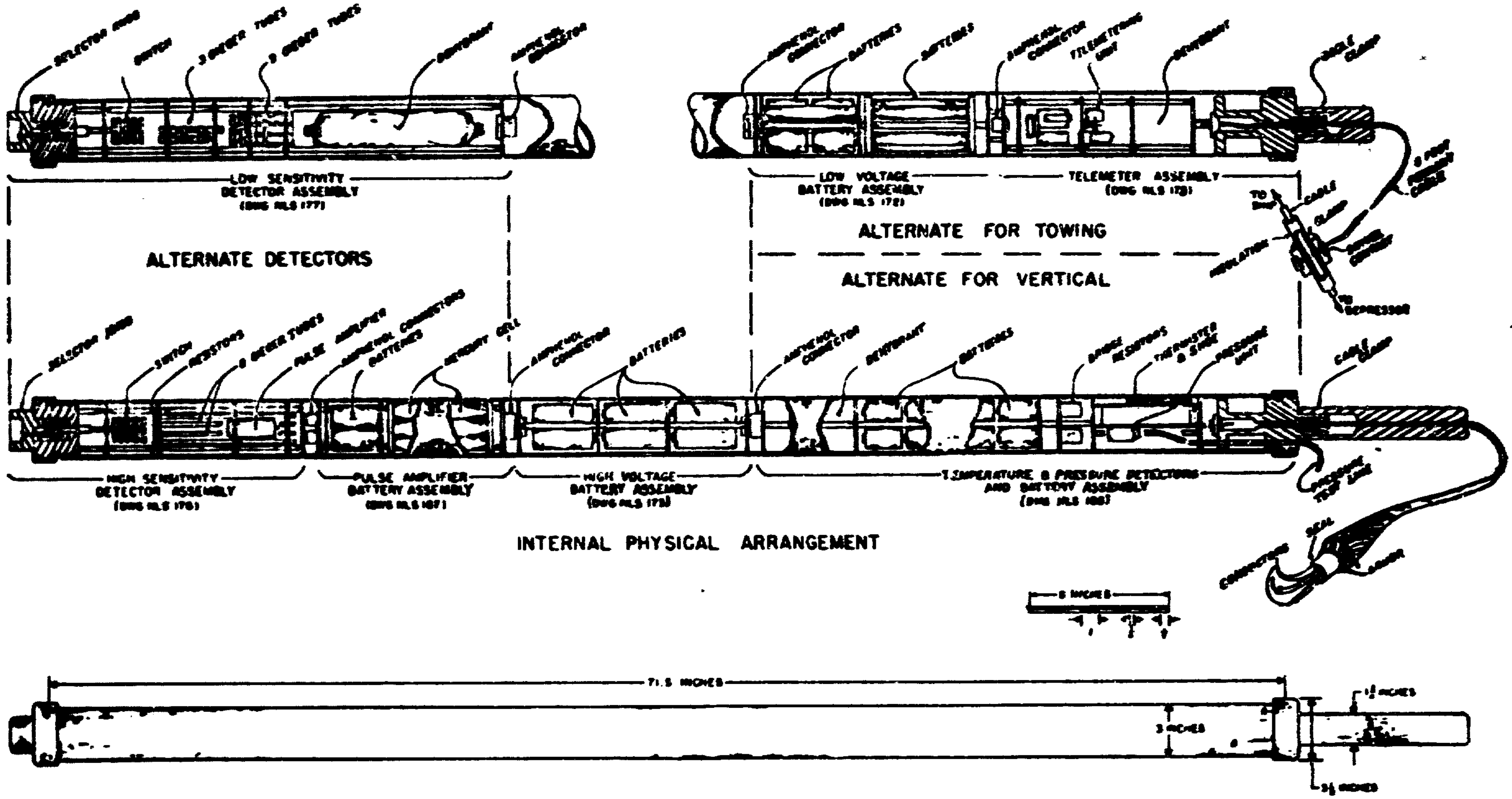


Fig. 3.50—Internal physical arrangement of radiation detector tube.

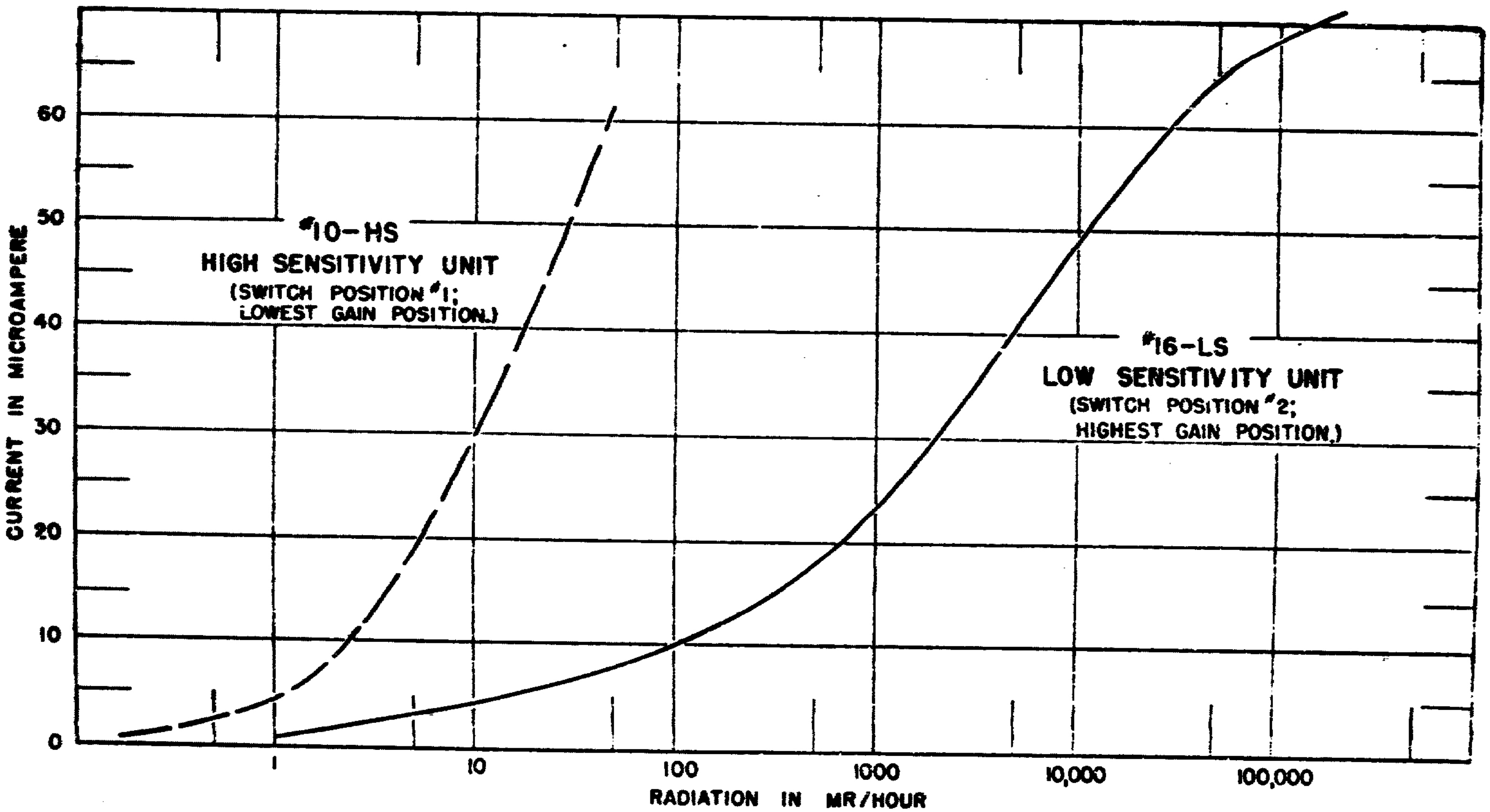


Fig. 3.51—Calibration curves, radiation detector tube.

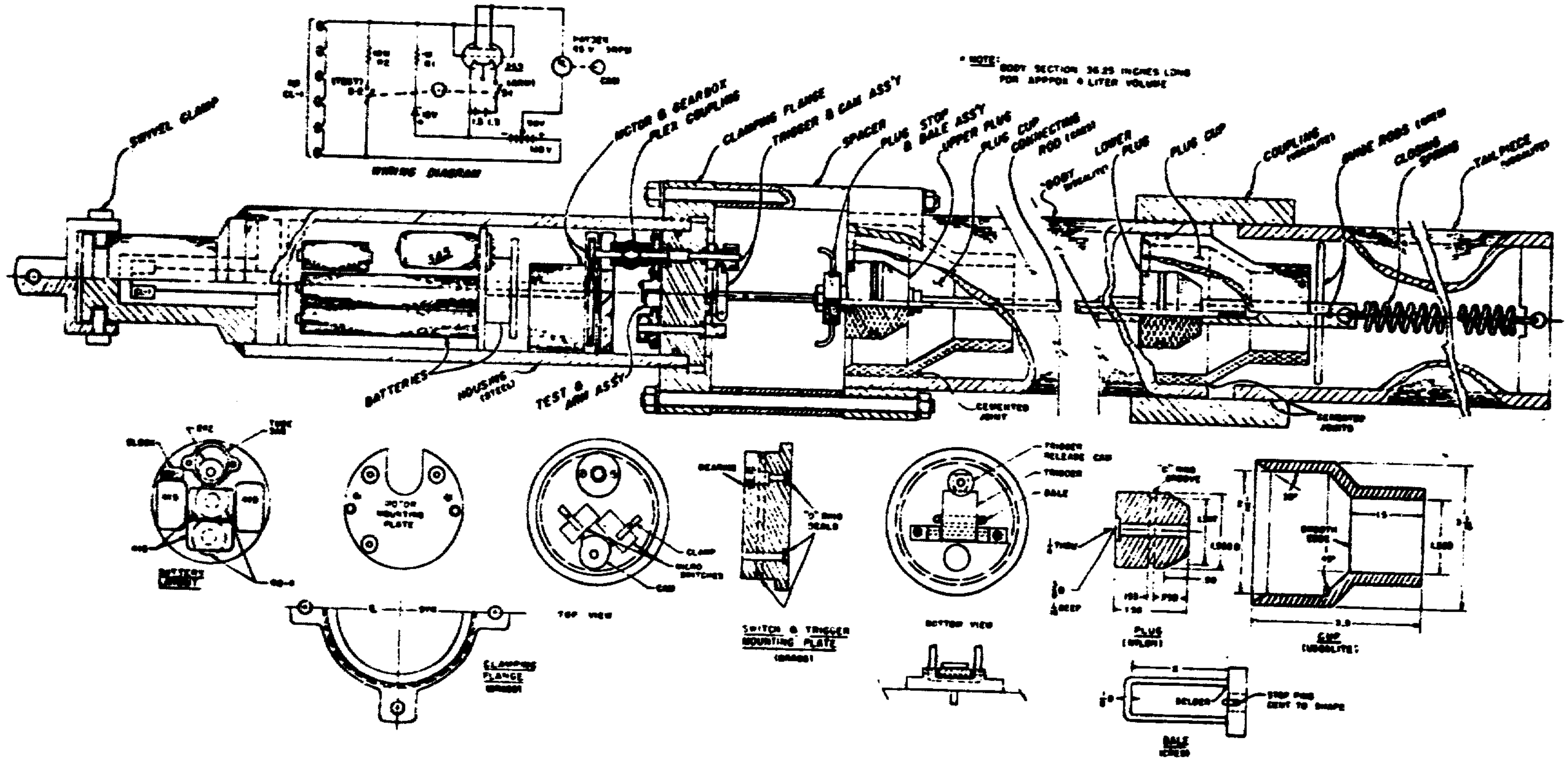


Fig. 3.52—Snap sampler and details.

PROJECT OFFICER: Frederic A. French

ORGANIZATION: U. S. Naval Radiological Defense Laboratory, San Francisco, Calif.

1. Objectives

a. Provide a dye marker at Surface Zero.

b. Measure the radioactive dosage at Surface Zero.

c. Collect representative samples of fall-out material for the purpose of determining: (1) the radioactive fall-out pattern, (2) the drop size and activity of such fall-out, and (3) the arrival of contamination as a function of time.

2. Results

a. Surface Zero was successfully marked with 1400 lb of sodium fluorescein dye. The marking persisted throughout the remainder of D-day.

b. Four DT 60 dosage indicators from Surface Zero were recovered giving an indicated dosage of 2650 ± 60 r. The absolute accuracy of this measurement may be more nearly ±25 per cent or ±900 r.

c. (1) Dense fall-out did not occur. A small portion (Cu, 1 per cent) of the total activity drifted downwind. The overwhelming preponderance of the active material rose with the dense plumes and settled rapidly back to the sea near Surface Zero.

(2) The particle size of air-borne debris was determined, and the distribution is shown in Fig. 3.53.

(3) The gamma detector system on the YAG-39 recorded 200 r/hr at H + 15.2 min at a distance of approximately 5 miles downwind. This and higher levels persisted until H + 21.3 min, when the level dropped again to 140 r/hr. During this period a rather uniform reading of 400 r/hr was obtained.

PROJECT 2.8 (Part I)

TITLE: Subsurface Configuration of the Array (Operation Wigwam, WT-1018, Secret, Paul L. Horrer)

PROJECT OFFICER: Paul L. Horrer

ORGANIZATION: Scripps Institution of Oceanography, University of California, La Jolla, Calif.

1. Objective

Determine the subsurface configuration of the array.

2. Results

It was found that the surface array was drifting at an average of 0.51 knot toward 277° relative to an anchored skiff (No. 6). The weapon and instrument cables tended outboard, primarily to starboard. In the fore-and-aft direction all cables for which there were data appear to have been well within the specified lower limit of acceptable accuracy (±50 ft) with which this project was concerned. Horizontal ranges from the weapon to instruments at all depths should not have varied by more than this amount from calculations made from surface and depth information alone.

3. Recommendations

The methods used in this project were satisfactory and should be included in future tests of this nature.

The test site chosen is suitable for future underwater detonations.

PROJECT 2.8 (Part II)

TITLE: Physical Oceanography of the Test Area (Operation Wigwam, WT-1019, Official Use Only, Paul L. Horrer)

PROJECT OFFICER: Paul L. Horrer

ORGANIZATION: Scripps Institution of Oceanography, University of California, La Jolla, Calif.

1. Objectives

a. Select, with Project 2.5, a test site.
b. Provide information for prediction of phenomenology.
c. Document the test with environmental information.

2. Results

Research cruises made to the general region during 1954 broadened available oceanographic knowledge about the area and enabled a tentative site selection and speculation on phenomenology. Final recommendations were based on oceanographic data (Figs. 3.54 to 3.57) collected in April 1955 and from 5 to 13 May 1955, just prior to the test. Results included: (a) contaminated waters moved westward from the test site at an average speed of about 0.1 knot (away from shore and fishing grounds), (b) dispersion of radioactivity at a given level was relatively slow during the first 10 days, but vertical current shear augmented its spreading, (c) depth of radioactivity measured at various times after the event appeared intimately associated with stability or vertical density gradient in the water, and (d) at H-hour the array and most ships of the task force were over relatively flat sea bottom, but a ridge 0.75 mile high existed about 5 miles south of Surface Zero. The low current speeds and movement of water away from land and ocean fishing grounds at the test area were desirable conditions.

3. Recommendation

From an oceanographic viewpoint, the area can be recommended for future tests of similar magnitude.

PROJECT 2.9

TITLE: Measurement of Secondary Effects (Operation Wigwam, WT-1020, Secret-FRD, L. W. Kidd)

PROJECT OFFICER: L. W. Kidd

ORGANIZATION: Scripps Institution of Oceanography, University of California, La Jolla, Calif.

1. Objectives

a. Obtain and analyze records of surface-water waves produced by the test.
b. Install and maintain special moored buoys in the immediate area as navigational aids for positioning and tracking of resultant phenomena.
c. Assist Project 2.6 (Part II) by developing and operating towed, high-speed telemetering equipment permitting measurement and survey of the subsurface radioactive masses.

2. Results

a. (1) Water waves were generated by the initial cavity at Surface Zero, and the first disturbance to propagate out was a very small trough.

(2) The theoretical predictions of phase zero's first crest and leading disturbance as a function of time and range fit the experimental data only when based upon an origin time (45 sec) and radius of generation (1550 ft) greater than those indicated by the amplitude (17 sec, 380 ft) data and maximum amplitude (32 sec, 430 ft) data. It is suggested that this was the result of the return to the surface of the plume water at a later time and greater range (Figs. 3.58 to 3.60).

(Text continues on page 121.)

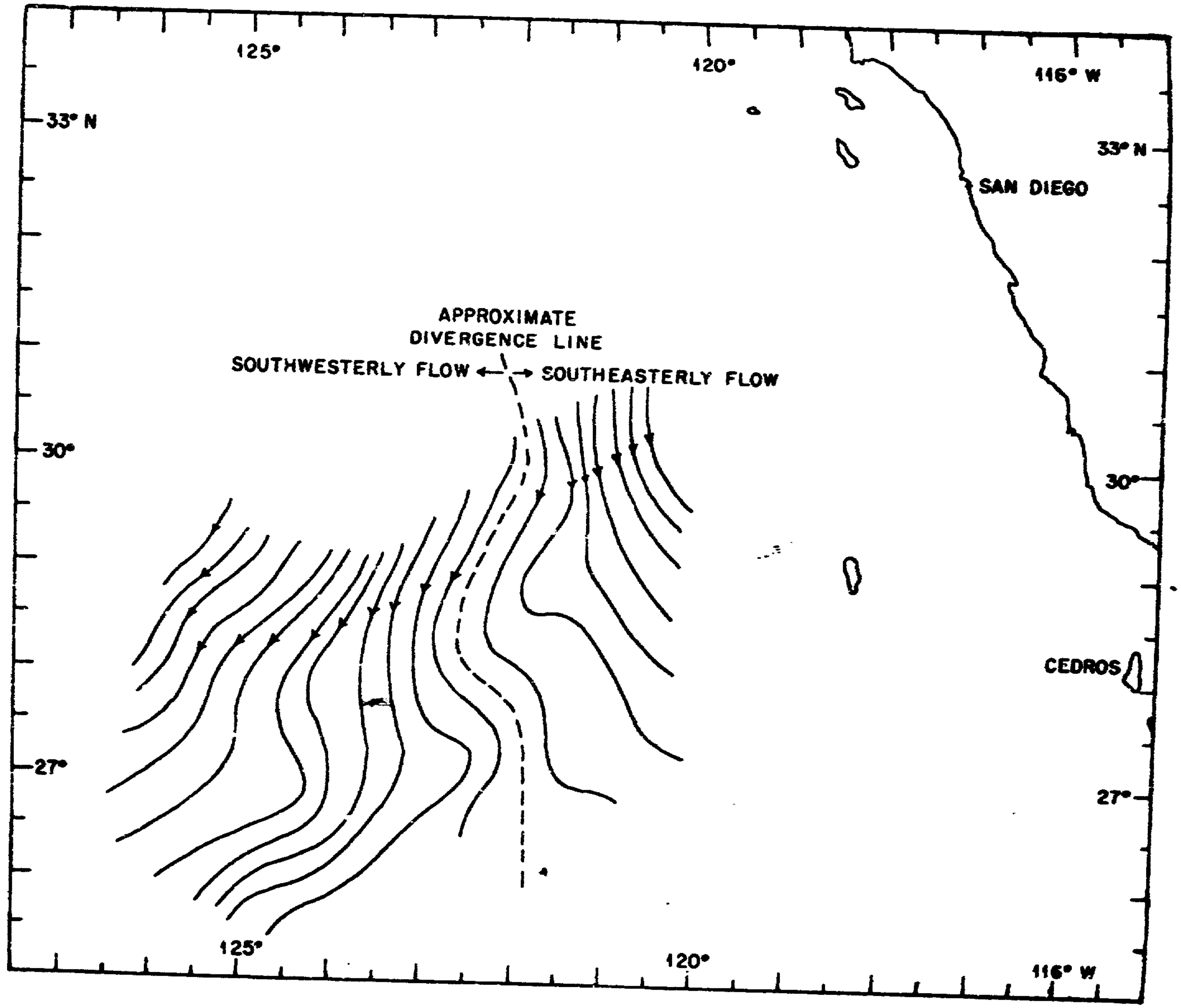


Fig. 3.54—Approximate surface streamlines.

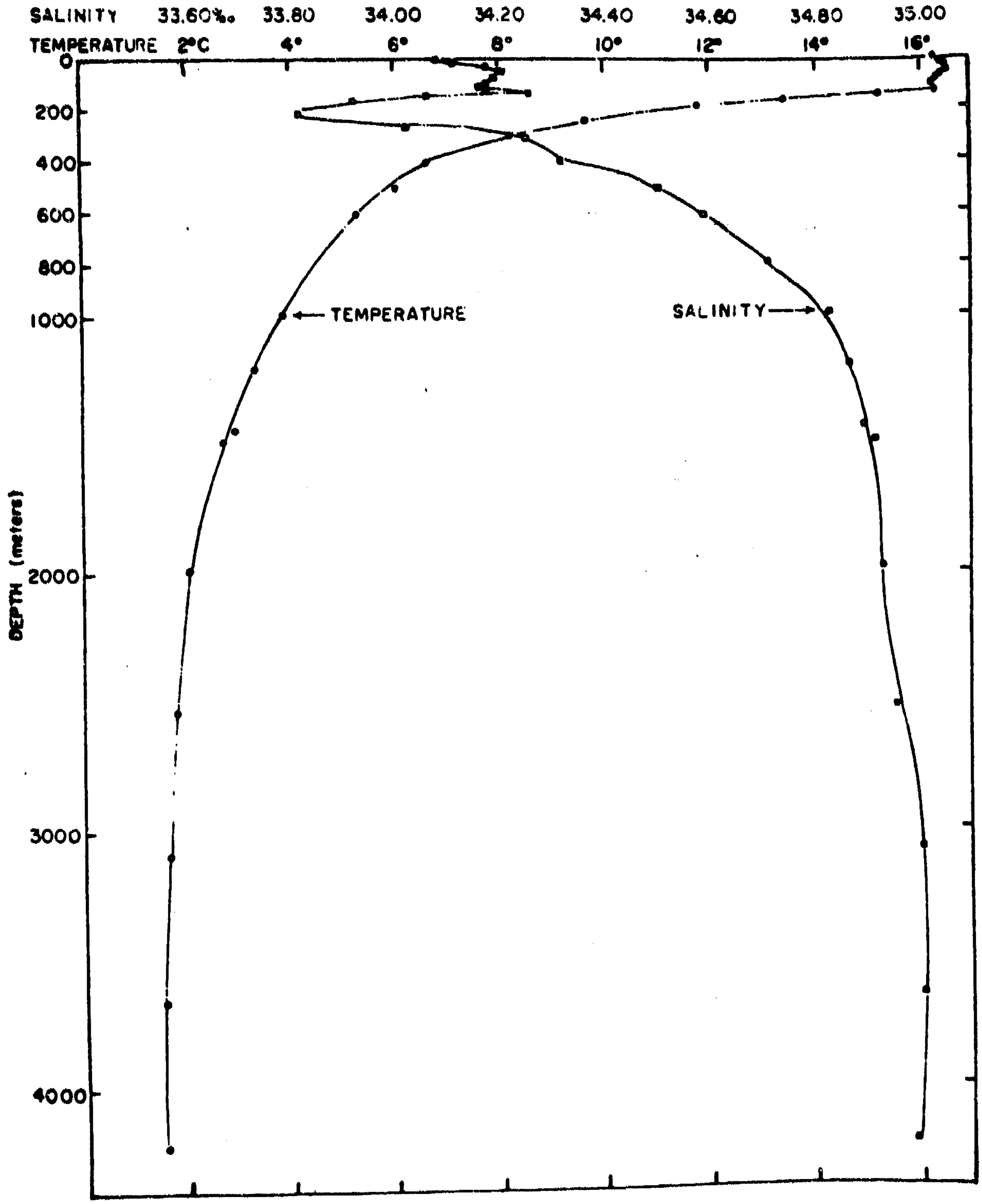


Fig. 3.55—Vertical distribution of temperature and salinity.

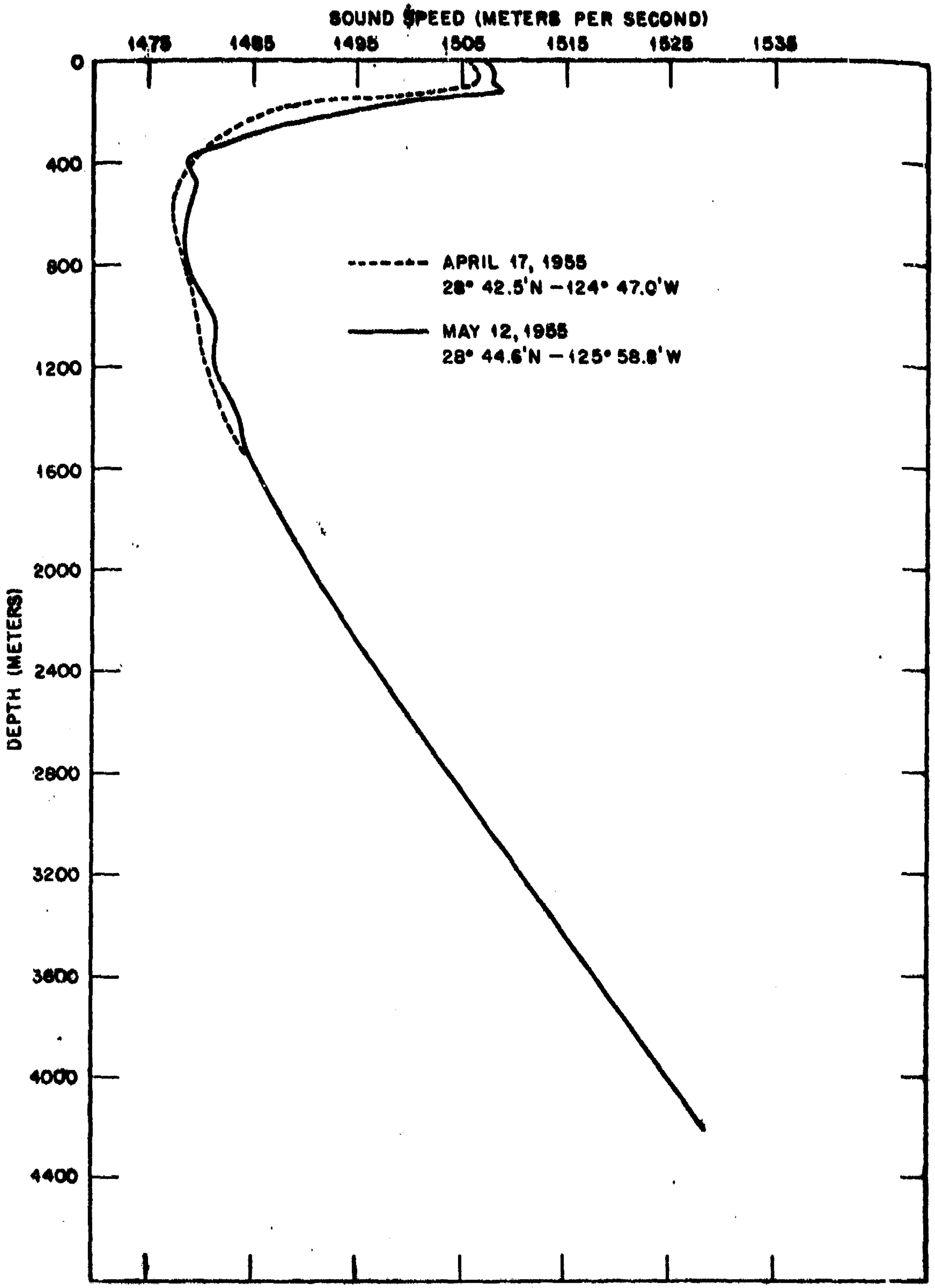


Fig. 3.56—Vertical distribution of calculated speed of sound.

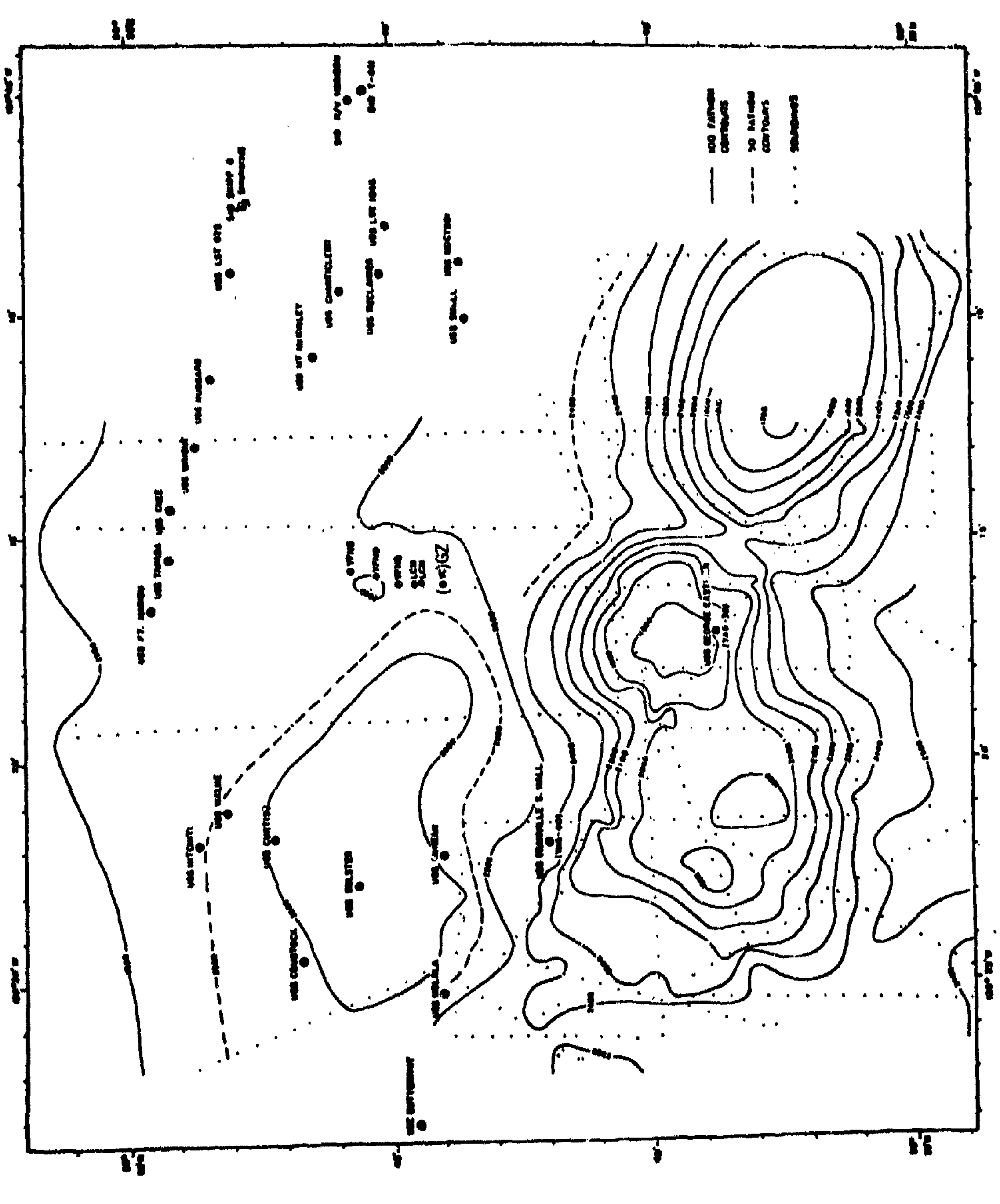


Fig. 3.57—Bottom topography and position of the array and task force ships at H-hour.

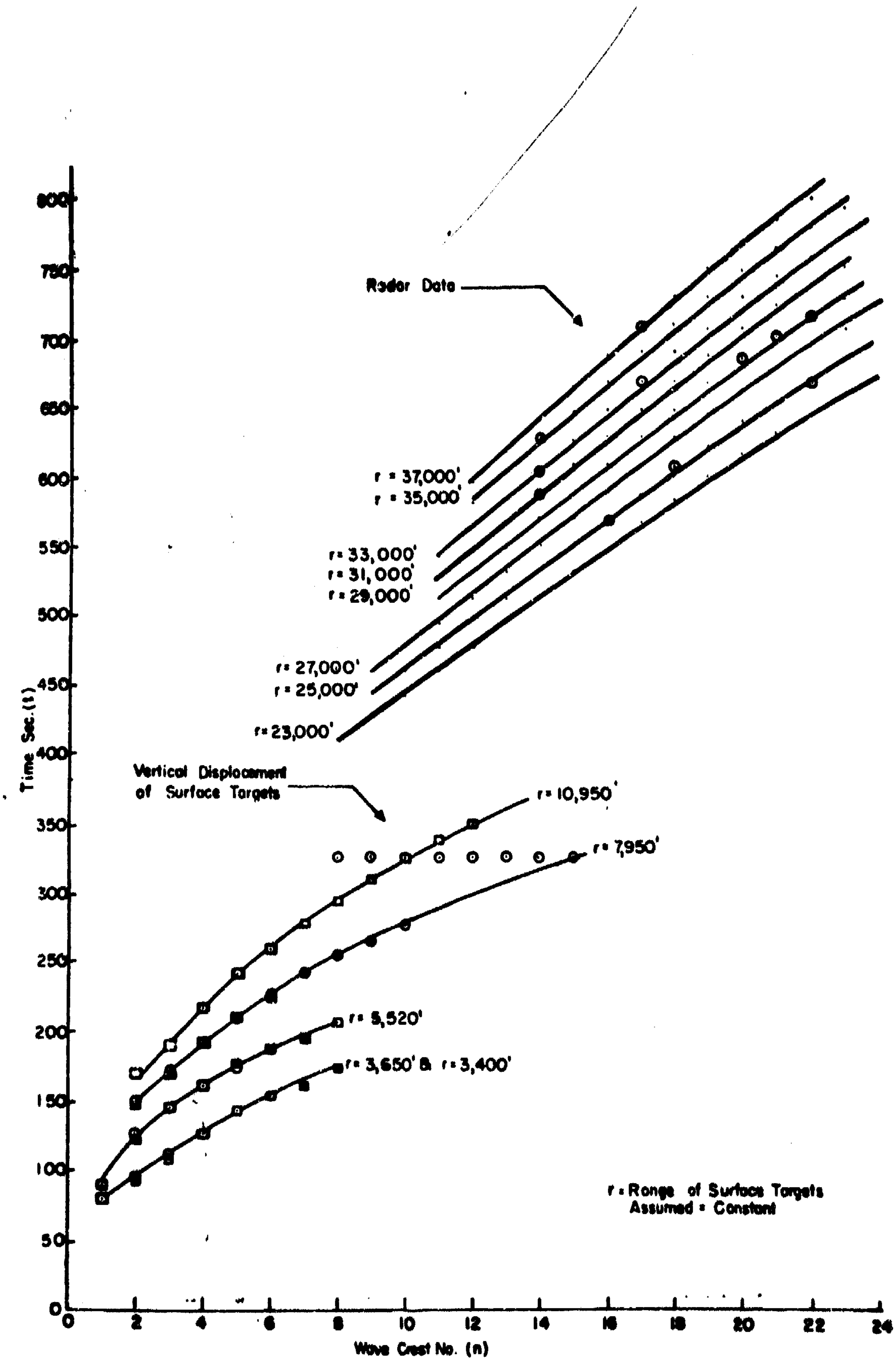


Fig. 3.58 — Crest time of arrival vs wave number for constant range.

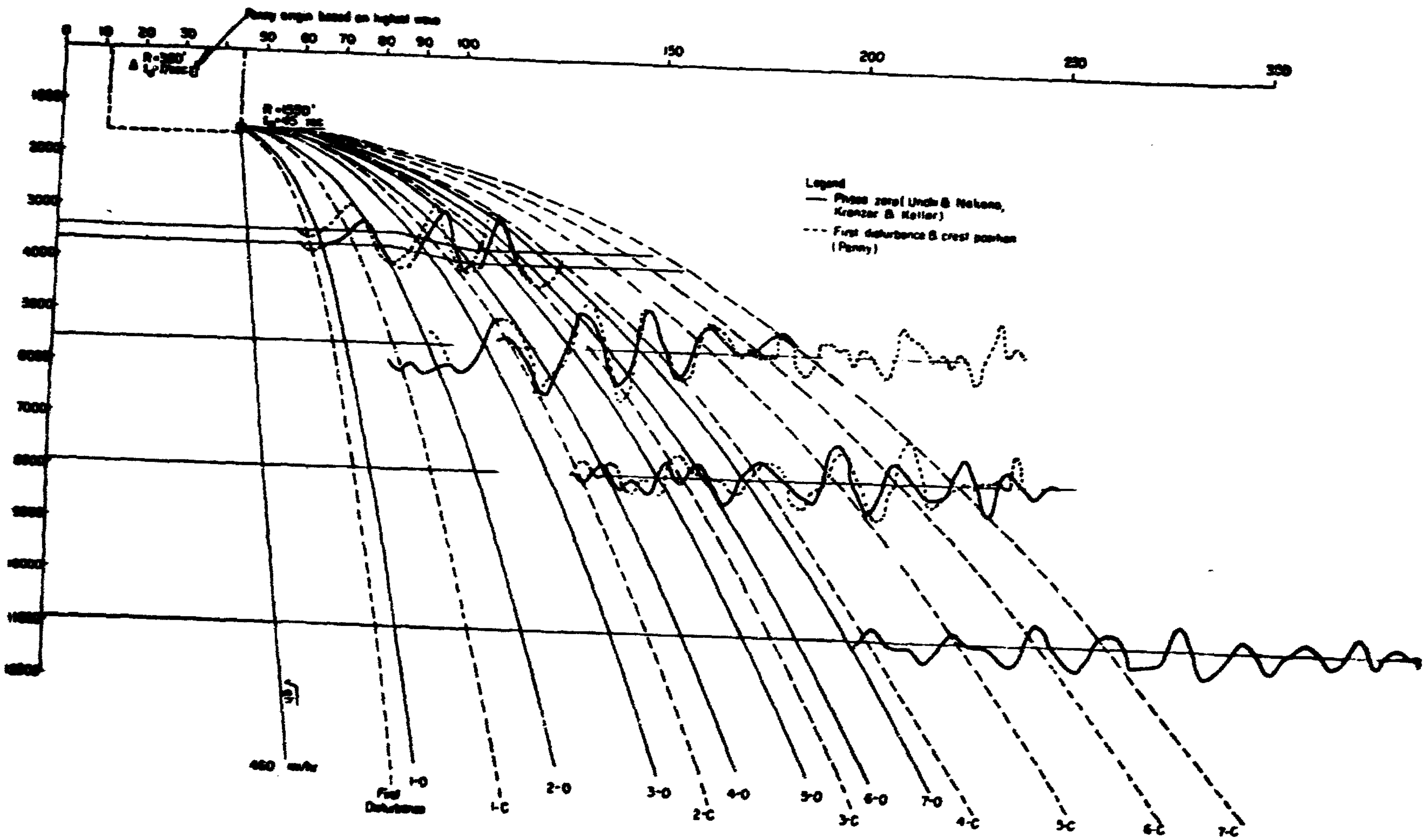


Fig. 3.59—Comparison of theoretical phase zero points, crest, and initial disturbance as a function of time for constant range.

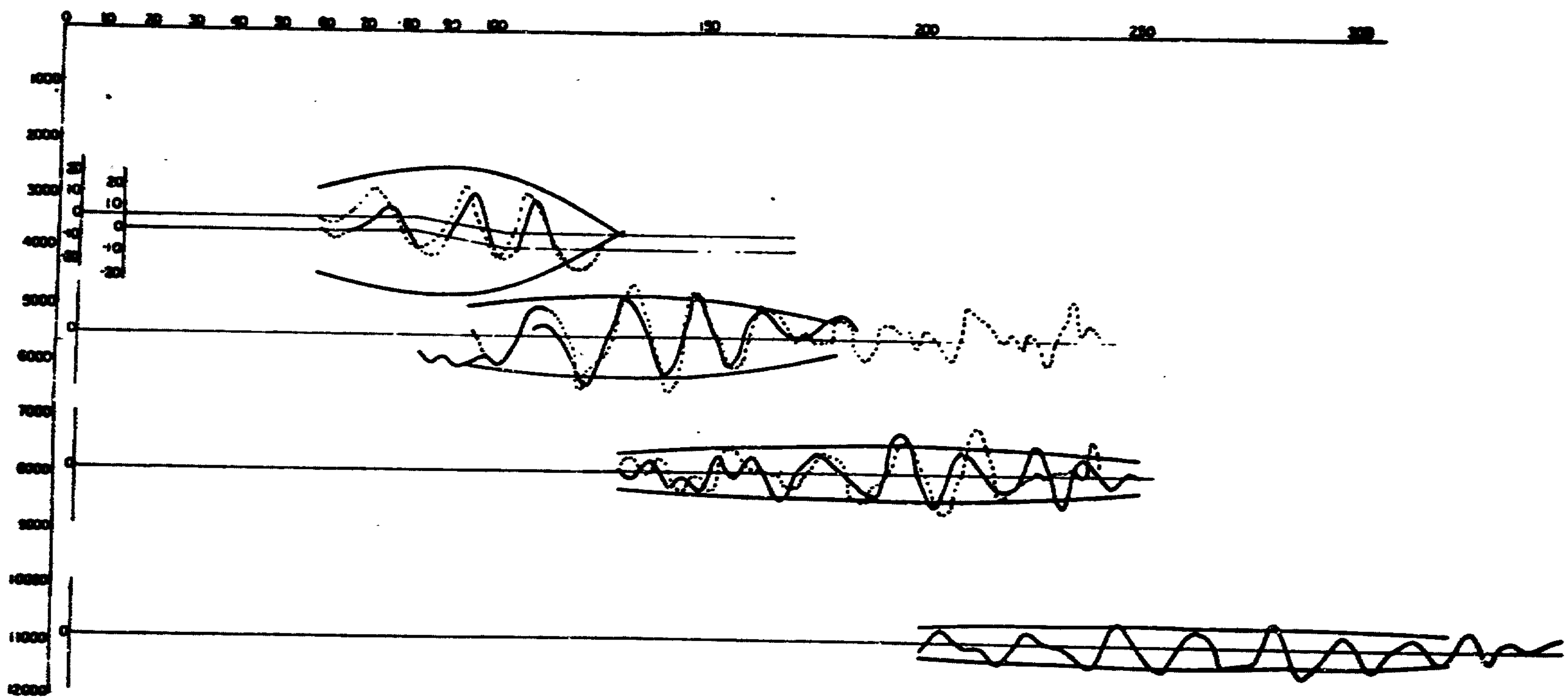


Fig. 3.60—Comparison of theoretical amplitude envelope curve as a function of time for constant ranges.

(3) The phase periods of the surface waves as a function of range and time can be calculated from the relation $T = 4\pi r/gt$.

(4) The energy of the surface waves represented 1.85 per cent of the total bomb yield.

(5) Insufficient data are available to scale the Wigwam waves to detonations at other depths or of different size.

b. Surface buoys installed as navigational aids represented an advance in the technique of providing fixed markers for navigation in the deep sea. The equipment performed satisfactorily and proved very useful in later operations.

c. Towed high-speed telemetering equipment for locating and surveying submerged radioactivity was used, but only for a comparatively short time. The equipment operated in a satisfactory manner demonstrating its usefulness.

3. Recommendations

a. The continued study of surface-water waves generated by explosions must be supported by future atomic weapons tests to permit predictions for other shot geometries.

b. Deep-moored surface buoys should be used in future tests where geographically fixed positions are required in deep water.

PROJECT 3.1

TITLE: Lethal Range of Wigwam Targets Based on Hull Response and Applied Pressure Measurements (Operation Wigwam, WT-1021, Confidential, Dr. George Chertock)

PROJECT OFFICER: Dr. George Chertock

ORGANIZATION: David Taylor Model Basin, Washington, D. C.

1. Objective

Estimate the lethal range of Wigwam targets by determining, from measurements upon the three target structures, the shock-wave loading and the response of the structures to this loading.

2. Results

The external pressures (Fig. 3.61) applied to the three SQUAW targets in Operation Wigwam were measured with pressure gauges, and the deformations of the hull were measured with strain and displacement gauges (Table 3.3).

The results indicated that SQUAW-12 was at a horizontal range of 5150 ft and a depth of 290 ft; the peak shock pressure at the hull was about 850 psi, and the target was destroyed, probably within 10 msec (Fig. 3.62).

SQUAW-13 was at a horizontal range of 7200 ft and a depth of 260 ft; the peak dynamic pressure at the hull was about 615 psi, and the hull was probably near collapse but did not rupture (Fig. 3.63).

It is estimated that the lethal horizontal range of the SQUAW target under the Wigwam test conditions is about 7000 ft for a depth of 250 ft and about 4500 ft for a depth of 70 ft. These results suggest an empirical equation for lethal shock pressure as a function of other pertinent quantities

$$P_s = (655 - P_0)\,(1 + e^{-\theta/15})\,(1 + e^{-T/15})$$

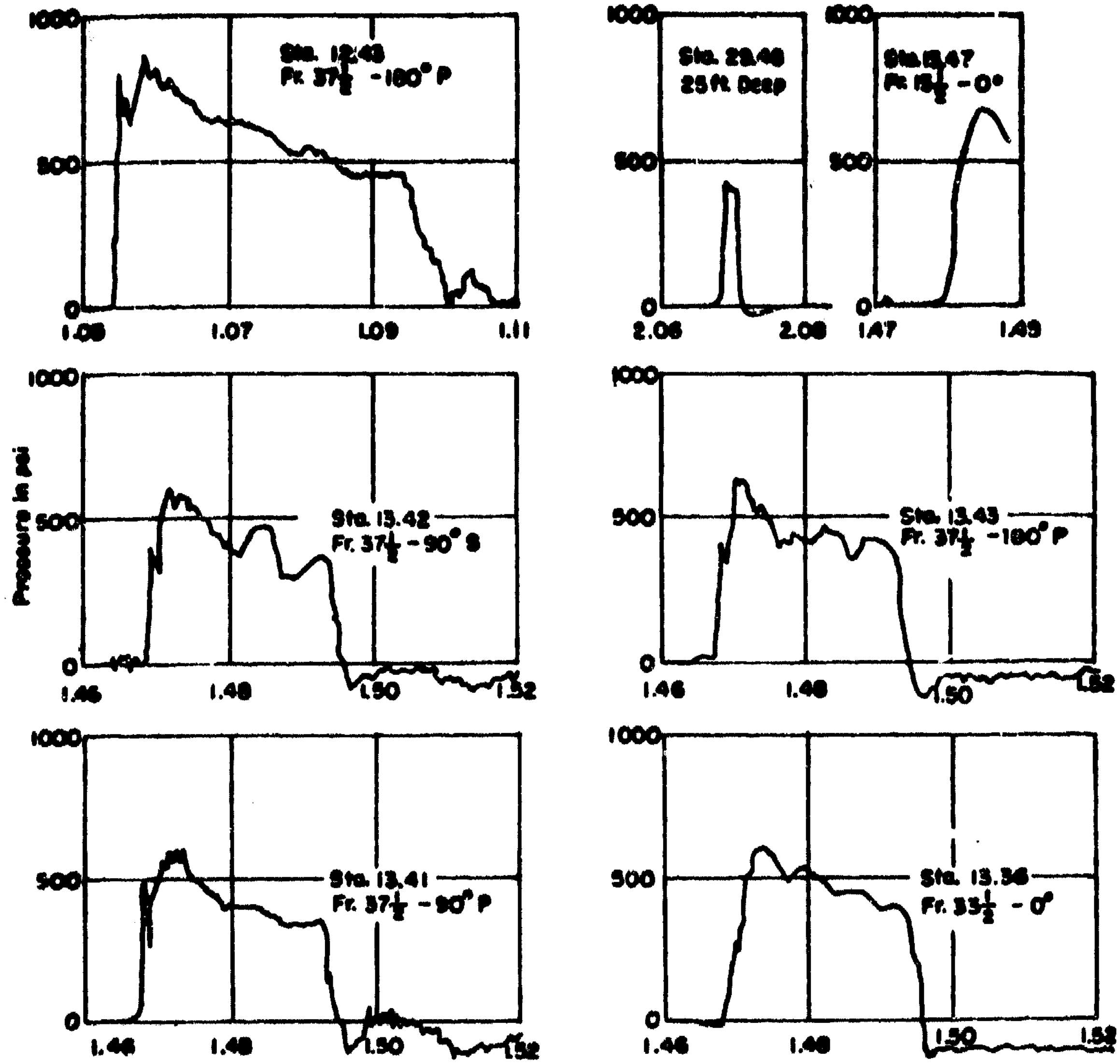
where P_s = the lethal shock peak pressure in pounds per square inch

P_0 = the hydrostatic pressure on the hull

θ = the time constant of the shock wave in milliseconds

T = the duration of the applied pressure in milliseconds

Finally, the following general formula is proposed which gives conditions for lethal attack by an atomic depth charge against a full-scale submarine:



Time in seconds

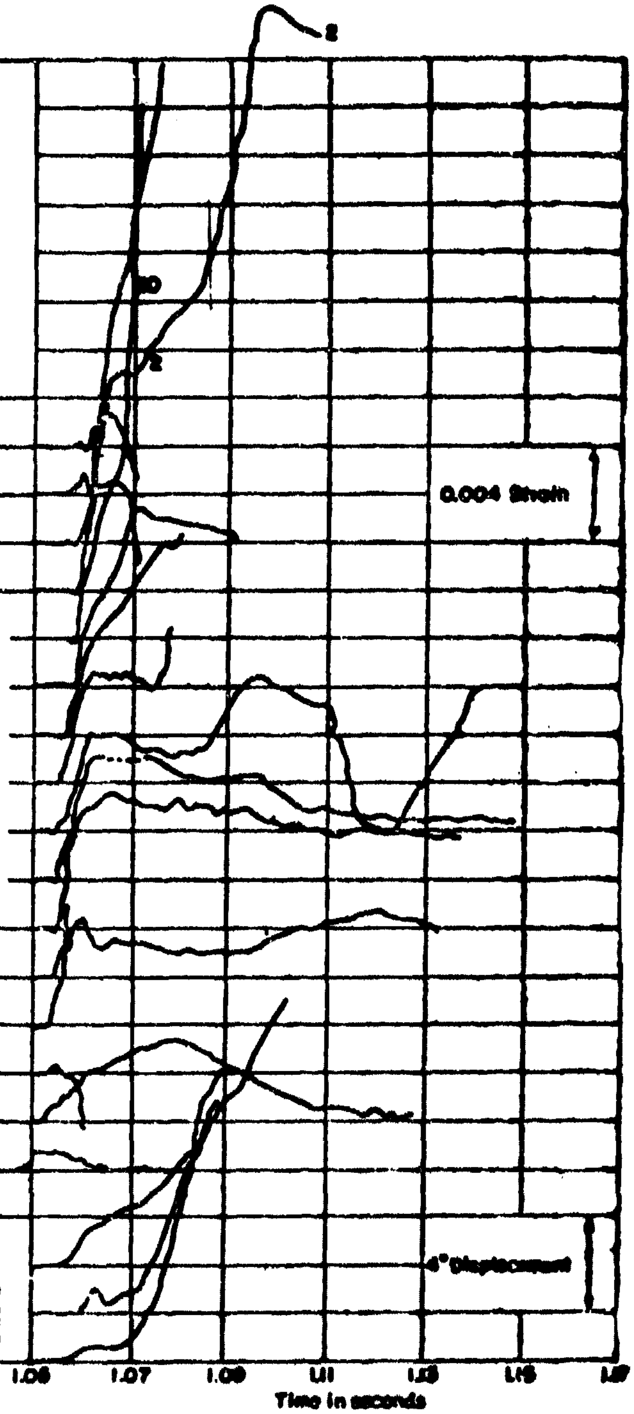
Fig. 3.61—Pressures measured at SQUAW targets.

TABLE 3.3—DESCRIPTION OF GAUGE STATIONS

No.	Description	Position		Recorded		
		Frame	Angle, deg	SQUAW-12	SQUAW-13	SQUAW-29
01	Circumferential strain on inside hull plating	15½	0	RC	RC	RC
02	Circumferential strain on inside hull plating	20½	0	RG	RG	RG
03	Circumferential strain on inside hull plating	25½	0	RC	RG	RG
04	Circumferential strain on inside hull plating	28½	0	F	RC	RC
05	Circumferential strain on inside hull plating	33½	0	RC	RC	RC
06	Circumferential strain on inside hull plating	33½	60S	RC	RG	RG
07	Circumferential strain on inside hull plating	33½	120S	RG	RG	RG
08	Circumferential strain on inside hull plating	30½	180	RC	RC	RC
09	Circumferential strain on inside hull plating	33½	60P	RC	RC	RC
10	Circumferential strain on inside hull plating	33½	120P	F	F	RG
11	Circumferential strain on inside hull plating	37½	0	F	RG	RG
12	Circumferential strain on inside hull plating	37½	16P	RC	F	RG
13	Circumferential strain on inside hull plating	37½	32P	F	F	RC
14	Circumferential strain on inside hull plating	37½	60P	F	RG	RG
15	Circumferential strain on inside hull plating	37½	90P	F	F	RG
16	Circumferential strain on inside hull plating	37½	120P	F	RG	RG
17	Circumferential strain on inside hull plating	37½	180	F	F	RC
18	Circumferential strain on inside hull plating	37½	60S	F	F	RG
19	Circumferential strain on inside hull plating	37½	120S	F	F	RG
20	Circumferential strain on flange of hull stiffener	22	0	RG	RG	RG
21	Circumferential strain on flange of hull stiffener	25	0	RG	RG	RG
22	Circumferential strain on flange of hull stiffener	34	0	F	F	RG
23	Circumferential strain on flange of hull stiffener	37	0	F	F	RG
24	Axial strain on hull plating	15½	0	RC	RC	RC
25	Axial strain on hull plating	25½	0	F	RG	RG
26	Axial strain on hull plating	37½	2P	RC	RC	RC
27	Axial strain on hull plating	33½	32S	F	RG	RG
28	Axial strain on hull plating	33½	180	F	RC	RC
29	Axial strain on hull plating	35¼	180	RC	RC	RC
30	Average circumferential strain on inside hull plating; 8 active gauges at ±15°, ±45°, ±75°, and ±105°	25½		RG	RG	RG
32	Strain on inside plating of hemispherical stern; 2 active gauges at right angles			RC	RC	RC
33	Diaphragm pressure gauge outside hull under walk at crown	15½	0	F	F	N
34	Diaphragm pressure gauge outside hull under walk at crown	20½	0	F	F	N
35	Diaphragm pressure gauge outside hull under walk at crown	26½	0	F	F	N
36	Diaphragm pressure gauge outside hull under walk at crown	33½	0	F	RG	N
37	Diaphragm pressure gauge outside hull under walk at crown	37½	0	F	F	N
38	Diaphragm pressure gauge in ballast tanks	15	90P	F	F	N
39	Diaphragm pressure gauge in ballast tanks	15	90P	F	F	RG
40	Diaphragm pressure gauge in ballast tanks	15	180S	F	F	RG
41	Diaphragm pressure gauge in ballast tanks	37	90P	F	RG	RG
42	Diaphragm pressure gauge in ballast tanks	37	90S	F	RG	N
43	Diaphragm pressure gauge in ballast tanks	37	180P	RG	RG	RG
46	Dummy bridge of 4 strain gauges	45		F	RC	RC
47	Piezoelectric pressure gauge outside hull under walk	15½	0	F	RC	RC
48*	Piezoelectric pressure gauge outside hull under walk	26½	0	F	F	RC*
49	Piezoelectric pressure gauge outside hull under walk	37½	0	F	RC	RC
50	Vertical displacement between hull stiffener and starboard motor block	35	0	F	F	RG
51	Vertical displacement between hull plating and starboard motor block	35½	0	RG	RG	RG
52	Horizontal displacement between hull stiffener and starboard motor block	35	90	RG	RG	RG

Notes: RC means gauge recorded with cathode-ray oscillograph; RG means gauge recorded with galvanometer oscillograph; F means station failed probably because of prior cable break; N means that gauge was in good condition but not used; all angles are measured relative to the center of the crown.

*Station 48 on SQUAW-29 was changed as described in WT-1021.



Station	Frame	Angle in degrees	Direction
1	$15\frac{1}{2}$	0	Circ.
24	$15\frac{1}{2}$	0	Axial
2	$21\frac{1}{2}$	0	Circ.
20	22	0	Circ.
21	25	0	Circ.
30	$28\frac{1}{2}$	—	Circ.
3	$25\frac{1}{2}$	0	Circ.
5	$33\frac{1}{2}$	0	Circ.
6	$28\frac{1}{2}$	60 S	Circ.
7	$35\frac{1}{2}$	120 S	Circ.
8	$35\frac{1}{2}$	180	Circ.
9	$33\frac{1}{2}$	60 P	Circ.
12	$37\frac{1}{2}$	16 P	Circ.
[illegible]	$37\frac{1}{2}$	0	Axial
[illegible]	$38\frac{1}{2}$	0	Axial
[illegible]	—	—	—
[illegible]	38	90	⟷
[illegible]	38	0	↕
51	$38\frac{1}{2}$	0	↕

Fig. 3.62—Strains and deflections measured on SQUAW-12.

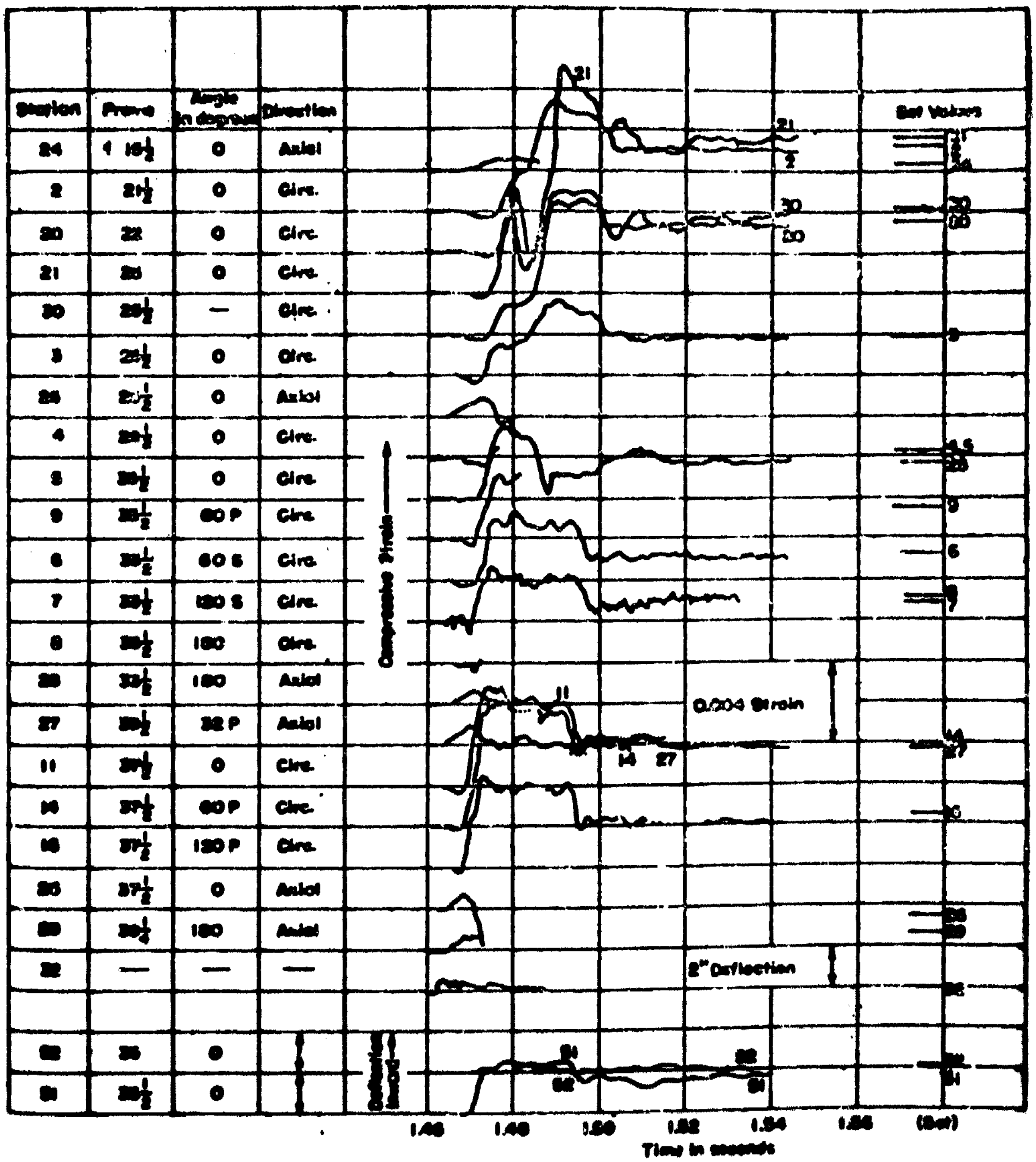


Fig. 3.63—Strains and deflections measured on SQUAW-13.

$$P_s = (kP_c - P_s)\,(1 + e^{-\theta/Tc})\,(1 + e^{-T/Tc})$$

where k = the ratio of dynamic to static yield strength
P_c = the static collapse pressure
Tc = a time characteristic of the target

All pressures are in pounds per square inch, and times are in milliseconds.

3. Recommendations

a. That all important modes of motion of the SQUAW be determined by a program of tests with SQUAW-29 and conventional charges without doing permanent damage to the hull.

b. Subsequently, the static collapse pressure of a portion of the hull should be measured in the Portsmouth pressure chamber.

PROJECT 3.2 (Part I)

TITLE: Hull Response and Shock Motion — Background, Instrumentation, and Test Results (Operation Wigwam, WT-1023, Confidential-RD, Harry L. Rich)

PROJECT OFFICER: Harry L. Rich

ORGANIZATION: David Taylor Model Basin, Washington, D. C.

1. Objectives

Provide instrumentation and make measurements on SQUAWS and YFNB's necessary for the determination of:

a. The rigid body motion of the hull as a function of time.
b. The motion of the hull at representative locations as a function of time.
c. The motion of simulated items of ship's heavy machinery as a function of time.
d. Shock spectra at representative locations on the vessels.

2. Results

Recordings were obtained from 70 per cent of the instruments from –2 sec to as late as +25 sec after the detonation. Records were obtained from every pickup installed on each YFNB and from 60 per cent of the pickups installed on the SQUAWS (Figs. 3.64 to 3.67). From the results of instrument checks made at the test site prior to the test, it was apparent that all failures were due to open circuits in the instrument cable joining the SQUAWS and YFNB's. This conclusion is substantiated by the fact that all recordings made from pickups on the YFNB's, where the special instrument cable was not necessary, were successful. The severe, continuous flexing and chafing of the instrument cable due to the rolling and pitching of the SQUAWS in the high swell on the way to and at the test site doubtlessly produced the damage.

For all six targets, the most severe motions were produced by the initial shock wave. Records given in Tables 3.6 and 3.7 are identified by position numbers keyed to Tables 3.4 and 3.5. Positive values refer to motions forward, upward, or to port.

No intelligible signals were received from SQUAW-12 later than about 0.5 sec after the arrival of the initial shock wave.

Oscillographic records obtained from SQUAW-13 were complete, showing that no appreciable flooding occurred during the recording interval.

Upon entry after return to port, SQUAW-29 showed no evidence of damage or flooding.

Some items of equipment were damaged on the YFNB-12. These included failure of hold-down bolts on a panel board of a 75-kw diesel alternator, fracture of the main casting on the deck winch at the bow, breakage of light bulbs, and the disarrangement of insecurely fastened items. This damage is not considered serious.

No significant damage was incurred by the other two YFNB targets; there were two broken light bulbs and some disarrangement of loose gear on YFNB-13.

(Text continues on page 135.)

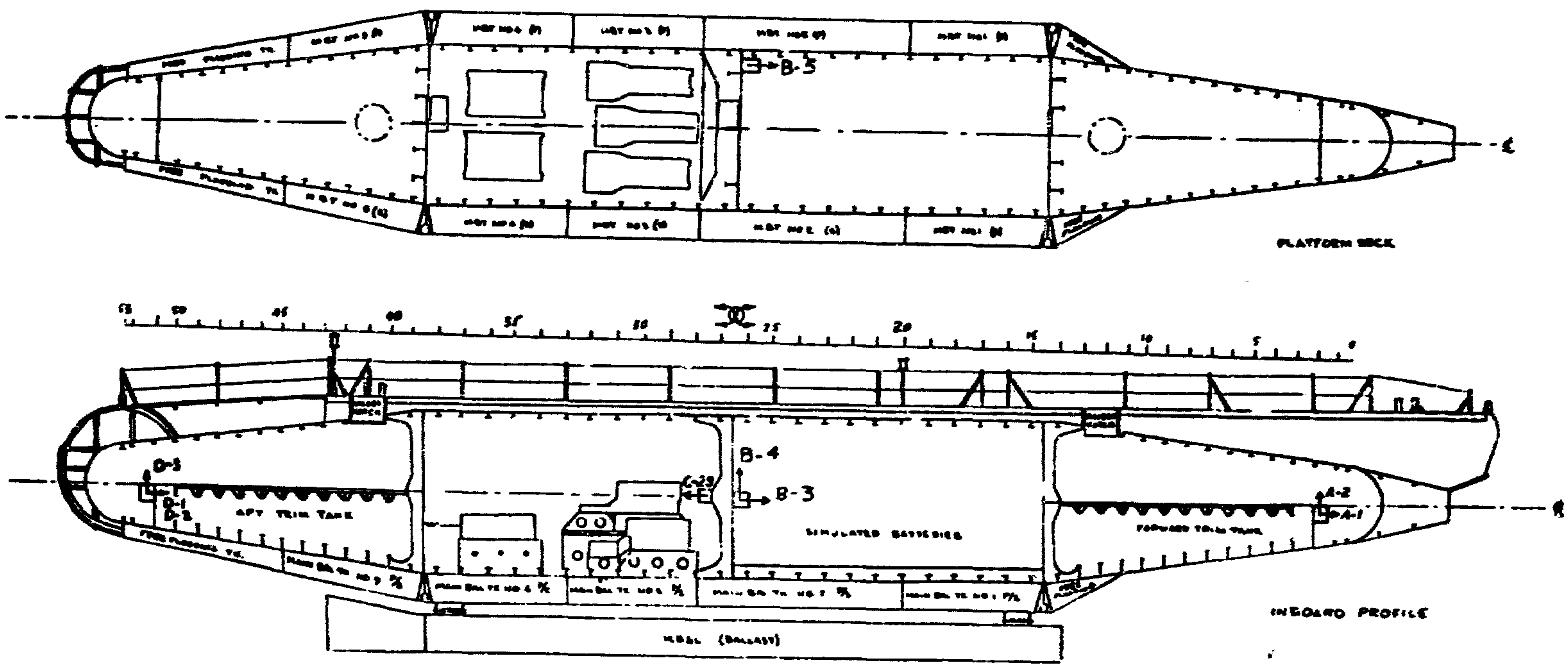


Fig. 3.64—Plan view and inboard profile of SQUAW, showing general layout, instrument locations, and orientations.

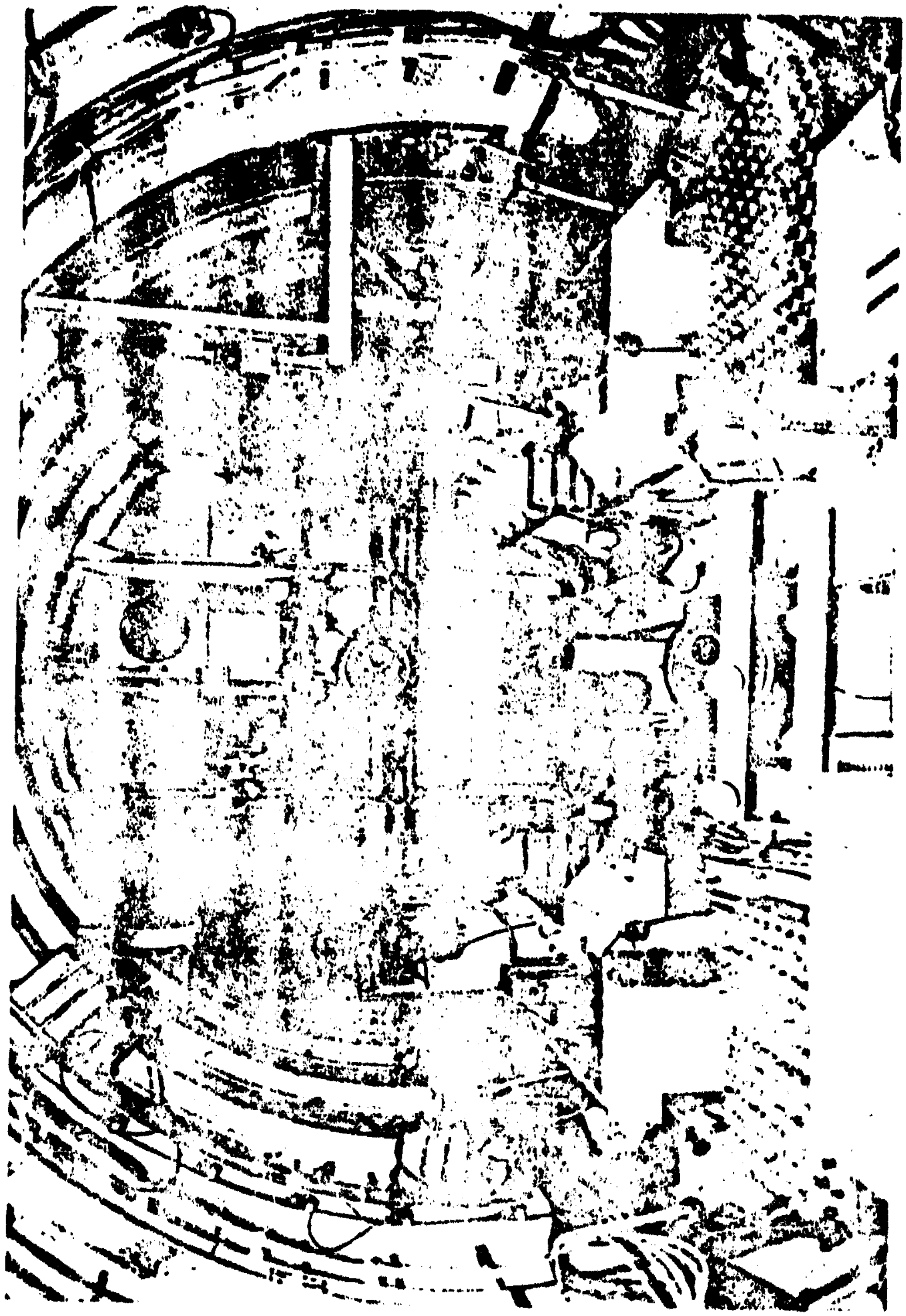


Fig. 3.65 — Photograph of engine compartment of a SQUAW.

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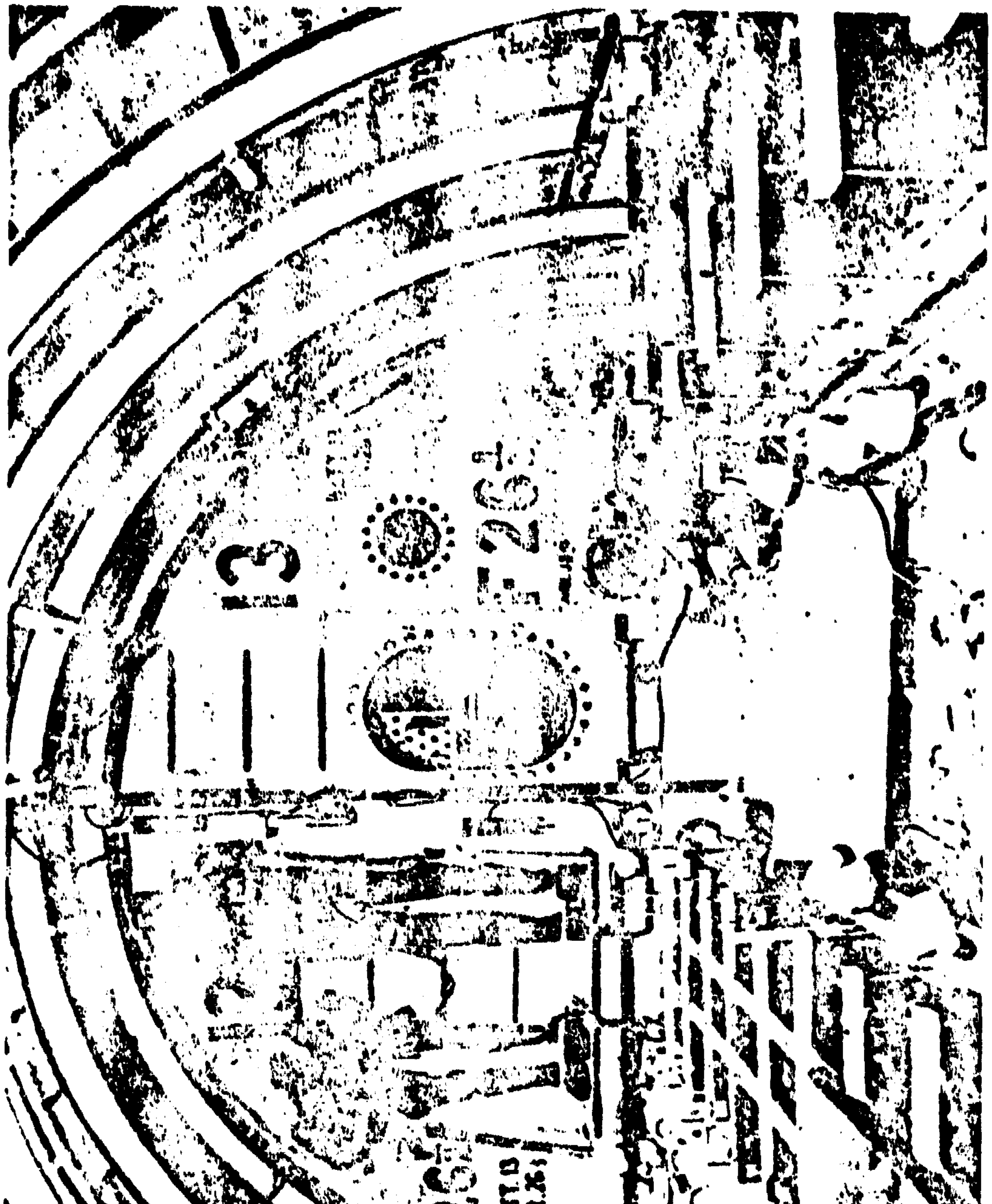

Fig. 3.66—Photograph of battery compartment of a SQUAW.

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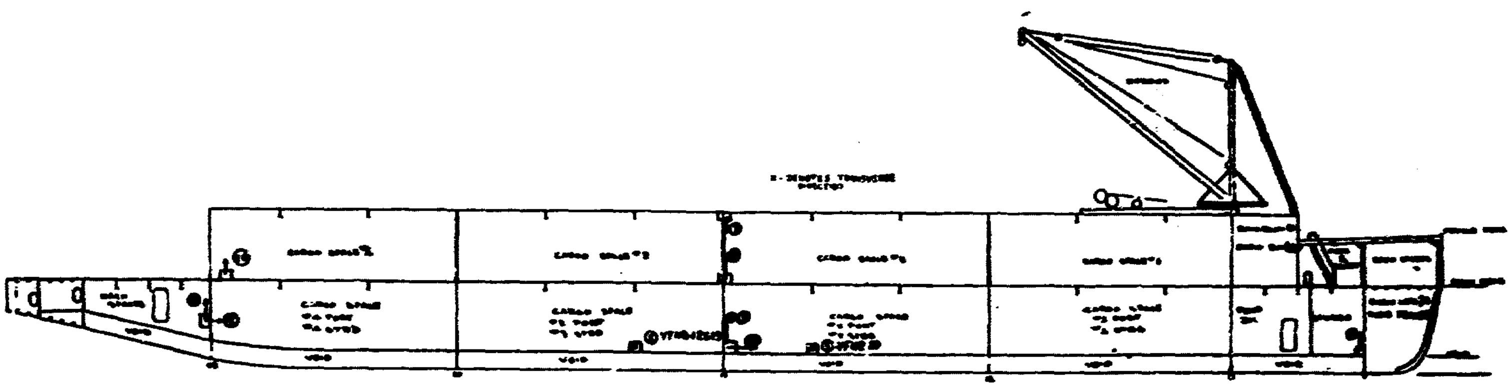

Fig. 3.67—Inboard profile view of YFNB.

TABLE 5.4—LOCATIONS OF INSTRUMENTS ON THE SQUAWS

Position*	Instrument*	Component measured	Structure to which attached	Vertical position	Transverse position	Longitudinal position: Frame	Longitudinal position: Description
A1	H	Axial	Fwd trim tank bhd	Near top of tank	1 ft from stbd hull	2	On fwd end of tank
A1	SSR	Axial	Fwd trim tank bhd	Near top of tank	2 ft from stbd hull	2	On fwd end of tank
A2†	BM	Vertical	Fwd trim tank bhd	Near top of tank	1 ft from port hull	2	On fwd end of tank
B1	H	Radial 12:00	Hull stiffener flange	Top of hull	CL of SQUAW	21	
B1	SSR	Radial 12:00	Hull stiffener flange	Top of hull	CL of SQUAW	21	
B2	H	Radial 10:30	Hull stiffener flange	45 deg from top of hull	45 deg from portside	21	
B2	SSR	Radial 10:30	Hull stiffener flange	45 deg from top of hull	45 deg from portside	21	
B3	H	Axial	Midship bhd	CL of SQUAW	CL of SQUAW	25½	On fwd side of bhd
B3	SSR	Axial	Midship bhd	CL of SQUAW	1 ft stbd of CL of SQUAW	25½	On fwd side of bhd
B4	BM	Vertical	Midship bhd	2 ft above CL of SQUAW	CL of SQUAW	25½	On fwd side of bhd
B4	SSR	Vertical	Midship bhd	CL of SQUAW	Near CL of SQUAW	27	On after side of bhd
B5	H	Axial	Midship bhd	CL of SQUAW	1 ft from port hull	25½	On fwd side of bhd
C1	H	Radial 12:00	Hull stiffener flange	Top of hull	CL of SQUAW	28	
C1	SSR	Radial 12:00	Hull stiffener flange	Top of hull	CL of SQUAW	28	
C2	H	Radial 10:30	Hull stiffener flange	45 deg from top of hull	45 deg from portside	28	
C2	SSR	Radial 10:30	Hull stiffener flange	45 deg from top of hull	45 deg from portside	28	
C3	H	Radial 12:00	Hull stiffener flange	Top of hull	CL of SQUAW	32	
C3	SSR	Radial 12:00	Hull stiffener flange	Top of hull	CL of SQUAW	32	
C4	H	Radial 10:30	Hull stiffener flange	45 deg from top of hull	45 deg from portside	32	
C4	SSR	Radial 10:30	Hull stiffener flange	45 deg from top of hull	45 deg from portside	32	
C5	H	Radial 9:00	Hull stiffener flange	CL of SQUAW	Portside	32	
C5	SSR	Radial 9:00	Hull stiffener flange	CL of SQUAW	Portside	32	
C6	BM	Axial	Fdtn of port eng	1 ft below eng mount	Inbd fdtn stiffener	30	3 ft aft of fwd end of eng
C6	SSR	Axial	Fdtn of port eng	2 ft below eng mount	Inbd fdtn leg	28	On fwd end of fdtn
C7	BM	Athwartship	Fdtn of port eng	2 ft below eng mount	CL of eng	29	2 ft aft of fwd end of eng
C7	SSR	Athwartship	Fdtn of port eng	Below eng mount	On inbd fdtn leg	29	2 ft aft of fwd end of eng
C8	BM	Vertical	Fdtn of port eng	1 ft above hull	On inbd fdtn leg	28½	Fwd end of fdtn
C8	SSR	Vertical	Fdtn of port eng	1 ft below eng mount	CL of eng	30	1 ft aft of center of eng
C9	BM	Axial	Port eng	On top of eng	Near inbd edge of eng	31	Near after end of eng
C9†	SSR	Axial	Port eng	Near top of eng	Near inbd edge of eng	28	On fwd end of eng
C9‡	SSR	Axial	Port eng	Near top of eng	Near inbd edge of eng	31	On after end of eng
C10	BM	Athwartship	Port eng	On top of eng	CL of eng	29½	2 ft aft of fwd end of eng
C10	SSR	Athwartship	Port eng	Near top of eng	On inbd side of eng	31	2 ft fwd of after end of eng
C11	BM	Vertical	Port eng	Near top of eng	On inbd side of eng	30	Center of eng
C11	SSR	Vertical	Port eng	On top of eng	Near outbd edge of eng	30½	Near after end of eng
C12	B	Vertical	Hull stiffener under center eng	Bottom of hull	CL of SQUAW	29	
C12	SSR	Vertical	Hull stiffener under center eng	Bottom of hull	CL of SQUAW	30	
C13	BM	Axial	Fdtn of stbd eng	1 ft below eng mounts	Inbd fdtn stiffener	30	3 ft aft of fwd end of eng
C13	SSR	Axial	Fdtn of stbd eng	2 ft below eng mounts	Inbd fdtn leg	28	On fwd end of fdtn
C14	BM	Athwartship	Fdtn of stbd eng	2 ft below eng mounts	CL of eng	29	2 ft aft of fwd end of eng
C14	SSR	Athwartship	Fdtn of stbd eng	Below eng mount	On inbd fdtn leg	29	2 ft aft of fwd end of eng
C15	BM	Vertical	Fdtn of stbd eng	1 ft above hull	On inbd fdtn leg	28½	Fwd end of fdtn
C15	SSR	Vertical	Fdtn of stbd eng	1 ft below eng mount	CL of eng	30	1 ft aft of center of eng
C16	BM	Axial	Stbd eng	On top of eng	Near inbd edge of eng	31	Near after end of eng

*See WT-1023.

†Installed on SQUAW-12 only.

‡Installed on SQUAWS 13 and 29 only.

TABLE 3.5—LOCATIONS OF INSTRUMENTS ON THE YFNB'S

						Longitudinal position	
Position*	Instrument*	Component measured	Structure to which attached	Vertical position	Transverse position	Frame	Description
1	B	Vertical	Inner bottom	On inner bottom	CL of YFNB	7	2 ft aft of bhd
1	SSR	Vertical	Inner bottom	On inner bottom	CL of YFNB	7	1 ft aft of bhd
2†	B	Vertical	Inner bottom	On inner bottom	2 ft from port hull	17	1 ft aft of bhd
2‡	B	Vertical	Inner bottom	On inner bottom	2 ft from port hull	17	1 ft fwd of bhd
2†	SSR	Vertical	Inner bottom	On inner bottom	2 ft from port hull	17	2 ft aft of bhd
2‡	SSR	Vertical	Inner bottom	On inner bottom	2 ft from port hull	17	2 ft fwd of bhd
3†	B	Vertical	Inner bottom	On inner bottom	CL of YFNB	17	2 ft aft of bhd
3‡	B	Vertical	Inner bottom	On inner bottom	CL of YFNB	17	2 ft fwd of bhd
3†	SSR	Vertical	Inner bottom	On inner bottom	CL of YFNB	17	3 ft aft of bhd
3‡	SSR	Vertical	Inner bottom	On inner bottom	CL of YFNB	17	2 ft fwd of bhd
4†	B	Axial	Transverse bhd	1 ft above inner bottom	CL of YFNB	17	On after side of bhd
4‡	B	Axial	Transverse bhd	1 ft above inner bottom	CL of YFNB	17	On fwd side of bhd
4†	SSR	Axial	Transverse bhd	2 ft above inner bottom	CL of YFNB	17	On after side of bhd
4‡	SSR	Axial	Transverse bhd	2 ft above inner bottom	CL of YFNB	17	On fwd side of bhd
5†	B	Athwartship	Vertical stiffener of longitudinal bhd	1 ft above inner bottom	On port side of bhd	18	
5‡	B	Athwartship	Vertical stiffener of longitudinal bhd	1 ft above inner bottom	On port side of bhd	16	
5†	SSR	Athwartship	Vertical stiffener of longitudinal bhd	2 ft above inner bottom	On port side of bhd	18	
5‡	SSR	Athwartship	Vertical stiffener of longitudinal bhd	2 ft above inner bottom	On port side of bhd	16	
6	B	Vertical	Main deck	On main deck	CL of YFNB	17	
6	SSR	Vertical	Main deck	On main deck	CL of YFNB	17	
7	B	Vertical	Transverse stiffener of top deck	On underside of top deck	CL of YFNB	17	
7	SSR	Vertical	Transverse stiffener of top deck	On underside of top deck	CL of YFNB	17	
8	B	Vertical	Longitudinal stiffener of center bhd	2 ft above inner bottom	Stbd side of bhd	23	1 ft aft of bhd
8	SSR	Vertical	Longitudinal stiffener of center bhd	2 ft above inner bottom	Stbd side of bhd	24	1 ft fwd of frame
9†	B	Axial	Transverse bhd	2 ft above inner bottom	1 ft stbd of CL	23	On after side of bhd
9‡	B	Axial	Vertical stiffener of center bhd	2 ft above inner bottom	Port side of bhd	24	On after side of frame
9	SSR	Axial	Vertical stiffener of center bhd	2 ft above inner bottom	Port side of bhd	24	On after side of frame
10	B	Vertical	Main deck	On main deck	CL of YFNB	23	3 ft fwd of bhd
10	SSR	Vertical	Main deck	On main deck	CL of YFNB	23	3 ft fwd of bhd
11†	BM§	Vertical	TMB instrument trailer	6 ft above main deck	Near center of trailer	22	On after interior side trailer
11‡	H	Vertical	TMB instrument trailer	4 ft above main deck, on trailer floor	Near center of trailer	22	Near fwd side of trailer

*See WT-1083.
†Installed on YFNB's 12 and 13 only.
‡Installed on YFNB-29 only.
§TMB bar-magnet meters at position 11 were fitted with a special suspension to make natural frequency of seismic element 1 cps.

TABLE 2.6—INITIAL SHOCK-MOTION DATA OBTAINED FROM VELOCITY METERS ON SQUAWS

[Positive motions are directed forward (axial motors) or inward (radial, vertical, and athwartship motors). At position B4, positive motion is upward]

			SQUAW-12						SQUAW-13						SQUAW-60					
			From oscillograph				Corrected data		From oscillograph				Corrected data		From oscillograph				Corrected data	
Position	Orientation	Location	Peak velocity, ft/sec	Rise time, msec	Acceleration, g Average	Acceleration, g Peak	Peak velocity, ft/sec	Initial peak displacement, in.	Peak velocity, ft/sec	Rise time, msec	Acceleration, g Average	Acceleration, g Peak	Peak velocity, ft/sec	Initial peak displacement, in.	Peak velocity, ft/sec	Rise time, msec	Acceleration, g Average	Acceleration, g Peak	Peak velocity, ft/sec	Initial peak displacement, in.
A1	Axial	Fwd trim tank	15.3	5.2	92	280	15.3	0.8	11.5	13.5	27	−130	11.8	1.5	−0.2	3.4	−8.2	56	*	*
A2	Vertical	Fwd trim tank	>6.3†	‡	‡	>600†	‡	‡	§	§	§	§	§	§	§	§	§	§	§	§
B1	Radial	Frame 21, 12:00	‡	‡	‡	‡	‡	‡	−8.1	19.6	−13	−300	−8.1	0.2	−8.7	6.2	−18	38	*	*
B2	Radial	Frame 21, 10:30	‡	‡	‡	‡	‡	‡	−11.8	4.4	−33	180	−11.8	−0.5	−2.3	5.2	−14	25	*	*
B3	Axial	Midship Bhd	13.6	3.1	140	380	13.6	1.9	8.4	16.7	18	−140	8.4	1.8	0.7	4.9	4.4	87	*	*
B4	Vertical	Midship Bhd	‡	‡	‡	‡	‡	‡	5.0	2.8	56	130	5.0	0.2	2.9	6.8	15	58	3.0	>1.2†
B5	Axial	Midship Bhd	‡	‡	‡	‡	‡	‡	6.8	16.3	12	56	*	*	‡	‡	‡	‡	‡	‡
C1	Radial	Frame 28, 12:00	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡
C2	Radial	Frame 28, 10:30	‡	‡	‡	‡	‡	‡	−10.4	2.9	−110	130	−10.4	−0.5	‡	‡	‡	‡	‡	‡
C3	Radial	Frame 32, 12:00	‡	‡	‡	‡	‡	‡	−9.5	14.2	−15	130	−9.5	0.3	‡	‡	‡	‡	‡	‡
C4	Radial	Frame 32, 10:30	‡	‡	‡	‡	‡	‡	−11.4	11.2	−32	−270	−11.4	−0.5	‡	‡	‡	‡	‡	‡
C5	Radial	Frame 32, 9:00	19.2	1.9	310	990	19.2	4.7	‡	‡	‡	‡	‡	‡	1.5	3.2	15	−57	*	*
C6	Axial	Fdtn of port eng	8.8	3.0	88	−210	8.8	0.2	11.2	7.6	47	−300	11.2	1.4	0.7	2.4	6.4	−26	*	*
C7	Athwartship	Fdtn of port eng	‡	‡	‡	‡	‡	‡	8.3	2.2	120	210	*	*	1.2	1.2	31	30	*	*
C8	Vertical	Fdtn of port eng	‡	‡	‡	‡	‡	‡	6.2	1.6	200	240	6.2	0.3	3.3	6.0	17	48	3.5	>1.1†
C9	Axial	Port eng	‡	‡	‡	‡	‡	‡	>6.5†	>30.4†	4.4	14	5.7	2.0	1.4	86	0.5	*	*	*
C10	Athwartship	Port eng	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡	0.2	44	0.1	*	*	*
C11	Vertical	Port eng	‡	‡	‡	‡	‡	‡	3.9	16.3	7.4	−34	3.9	1.3	2.0	20.8	2.2	3	3.1	2.3
C12	Vertical	Under center eng	‡	‡	‡	‡	‡	‡	8.1	1.5	170	600	8.1	0.5	3.2	5.8	17	84	*	*
C13	Axial	Fdtn of stbd eng	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡	−0.9	6.4	−3.9	23	*	*
C14	Athwartship	Fdtn of stbd eng	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡	−1.1	11.4	−3.0	−20	*	*
C15	Vertical	Fdtn of stbd eng	>10.3†	>12.9†	33	300	*	*	‡	‡	‡	‡	‡	‡	3.4	4.5	24	64	*	*
C16	Axial	Stbd eng	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡	1.4	6.4	6.0	18	*	*
C17	Athwartship	Stbd eng	−13.5	12.6	−84	230	*	*	‡	‡	‡	‡	‡	‡	−2.9	0.2	−9.4	22	*	*
C18	Vertical	Stbd eng	‡	‡	‡	‡	‡	‡	7.6	5.0	47	30	7.6	0.4	3.6	6.8	16	32	*	*
C19	Axial	Center eng	−6.2	34.5	−7.9	−270	−6.2	0.7	‡	‡	‡	‡	‡	‡	2.0	32.5	1.9	−10	*	*
C20	Vertical	Center eng	‡	‡	‡	‡	‡	‡	7.3	3.0	61	117	7.3	0.4	3.7	6.0	15	−34	*	*
C21	Athwartship	Port generator	11.0	29.2	17	46	11.2	>6.4†	‡	‡	‡	‡	‡	‡	0.2	37	6.2	*	*	*
C22	Vertical	Port generator	12.2	18.1	31	86	12.1	7.0	‡	‡	‡	‡	‡	‡	2.1	71.0	2.1	80	2.6	1.8
C23	Athwartship	Stbd generator	−9.6	9.3	−22	87	−9.8	−1.5	‡	‡	‡	‡	‡	‡	1.3	6.2	6.5	30	*	*
C24	Vertical	Stbd generator	3.5	20.8	4.1	44	*	*	9.3	3.5	86	114	9.2	0.8	2.7	6.6	13	40	*	*
C25	Axial	Fdtn of port motor	6.1	2.0	130	290	6.1	0.9	‡	‡	‡	‡	‡	‡	0.5	6.2	2.6	16	*	*
C26	Vertical	Fdtn of stbd motor	11.8	22.1	16	−370	11.6	>7.8†	4.4	2.1	44	240	4.5	0.4	2.8	11.4	7.6	37	*	*
C27	Axial	Stbd motor	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡	>0.2†	6.8	2.3	−31	*	*
C28	Vertical	Stbd motor	>7.7†	>33.7†	7.1	10	*	*	4.6	5.4	27	80	4.6	0.6	2.0	6.1	11	23	*	*
D1	Axial	After trim tank	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡	§	§	§	§	§	§
D8	Vertical	After trim tank	−3.0	8.7	−130	−800	*	*	§	§	§	§	§	§	§	§	§	§	§	§

*Value not computed. †Record or analysis incomplete. Largest value observed is shown, but record indicates that larger values probably occurred.
‡No signal received on this channel. §No meter installed at this position.

TABLE 3.7—INITIAL SHOCK-MOTION DATA OBTAINED FROM VELOCITY METERS ON YFNB'S

[Positive motions are directed forward (axial meters), upward (vertical meters), or to port (athwartship meters)]

Position	Orientation	Location	YFNB-12 From oscillograph Peak velocity, ft/sec	YFNB-12 From oscillograph Rise time, msec	YFNB-12 From oscillograph Acceleration, g Average	YFNB-12 From oscillograph Acceleration, g Peak	YFNB-12 Corrected data Peak velocity, ft/sec	YFNB-12 Corrected data Initial peak displacement, in.	YFNB-13 From oscillograph Peak velocity, ft/sec	YFNB-13 From oscillograph Rise time, msec	YFNB-13 From oscillograph Acceleration, g Average	YFNB-13 From oscillograph Acceleration, g Peak	YFNB-13 Corrected data Peak velocity, ft/sec	YFNB-13 Corrected data Initial peak displacement, in.	YFNB-29 From oscillograph Peak velocity, ft/sec	YFNB-29 From oscillograph Rise time, msec	YFNB-29 From oscillograph Acceleration, g Average	YFNB-29 From oscillograph Acceleration, g Peak	YFNB-29 Corrected data Peak velocity, ft/sec	YFNB-29 Corrected data Initial peak displacement, in.
1	Vertical	Bottom, bow	4.7	17.1	8.5	120	*	*	2.2	20.3	3.4	57	*	*	1.0	3.5	0.9	9	*	*
2	Vertical	Bottom, midship portside	6.2	9.6	20	210	*	*	3.3	13.8	7.4	77	*	*	1.6	20.7	2.4	40	*	*
3	Vertical	Bottom, midship	6.9	9.9	22	−170	6.8	5.2	2.9	10.0	9.0	−43	3.1	>1.0†	1.3	8.6	4.7	28	1.4	>0.8†
4	Axial	Midship bhd	0.7	0.4	54	69	*	*	0.4	2.2	5.6	21	*	*	−0.1	1.8	−1.7	8	*	*
5	Athwartship	Midship bhd	−1.1	4.5	−7.6	−80	*	*	−0.4	4.5	−2.8	20	*	*	−0.2	10.9	−0.6	8	*	*
6	Vertical	Main deck, midship	6.8	13.2	16	−130	*	*	2.9	8.0	11	64	*	*	1.3	8.1	5.0	34	*	*
7	Vertical	Top deck, midship	6.3	7.3	27	−58	*	*	3.4	23.6	4.5	28	*	*	2.2	22.9	3.0	17	*	*
8	Vertical	Bottom, stern	6.9	6.9	31	63	*	*	3.7	6.5	21	57	*	*	1.2	6.6	4.3	30	*	*
9	Axial	Bhd, stern	−0.8	3.7	−6.7	−24	*	*	0.3	1.1	8.5	21	*	*	−0.2	1.9	−6.2	17	*	*
10	Vertical	Main deck, stern	7.2	10.8	21	130	*	*	3.2	9.9	10	62	*	*	1.3	11.0	3.7	−12	*	*
11	Vertical	Instrumentation trailer	4.2	58.6	2.2	*	*	*	2.1	69.7	0.9	*	*	*	0.6	46	0.4	*	*	*

*Value not computed.

†Record or analysis incomplete. Largest value observed is shown, but record indicates that larger values probably occurred.

PROJECT 3.2 (Part II)

TITLE: Hull Response and Shock Motion—Discussion and Analysis (Operation Wigwam, WT-1024, Secret-RD, Harry L. Rich)

PROJECT OFFICER: Harry L. Rich

ORGANIZATION: David Taylor Model Basin, Washington, D. C.

1. Objective

Analyze and interpret the results obtained by Project 3.2 (Part I).

2. Results

a. There were several separate excitations of the targets. Within a horizontal range of about 13,000 ft, the most severe excitation was caused by a shock wave resulting from the explosion and transmitted directly to the targets. Smaller excitations were associated with the collapse of the first bubble resulting from the explosion and with the reflection of the initial shock wave from the ocean floor. Beyond about 13,000 ft the vertical shock motions on surface targets due to the reflected shock wave may have been larger than those due to the direct shock wave. Severe damage was associated with the direct initial shock wave only, but the intensity of the reflected shock wave depends on the character of the ocean bottom and may under certain circumstances cause minor damage at quite large standoffs. (Some shock spectra are shown in Figs. 3.68 to 3.71.)

b. The surfacing-damage (severe equipment damage) range for submarines at a depth of about 250 ft was less than about 7200-ft horizontal standoff.

c. Shock damage to surface ships resulting from the initial shock wave was light but widespread at a horizontal range of about 5400 ft from the point of explosion and inappreciable at a range of about 7700 ft.

d. Type 6 ACL shock mounts are effective in attenuating shock transmission to mounted equipment in submarines at horizontal standoffs of about 7200 ft or more. They are ineffective at loads large enough to collapse the hull.

e. Gross motions of submerged targets were slightly less than the motion computed for a rigid cylinder acted upon by free-field pressures associated with the explosion and the effect of the surface. The maximum hull shock velocities attained under lethal atomic attack are much smaller than the hull velocities associated with lethal attack by conventional weapons.

f. Vertical motions of surface targets are given approximately by the free-field vertical motion of the surface water under the action of the shock-wave pressures. Peak vertical velocity is a good criterion for damage to be expected, and comparison with damage for surface targets attacked by conventional underwater explosions can be made by comparing peak velocities. Axial and athwartship motions of surface targets are small compared with vertical motions.

3. Recommendations

In order to provide a more valid basis for a comparison of the effects of conventional and atomic weapon attacks on submarine hulls and equipment, it is recommended that instrumented tests with conventional weapons be conducted on the remaining SQUAW-29 target. Initially, at least, these tests should be conducted at less than damaging radius in order that a maximum of shock information may be obtained.

PROJECT 3.2.1

TITLE: Shock Motion of YFNB Targets (Operation Wigwam, WT-1025, Confidential-RD, R. E. Blake)

PROJECT OFFICER: J. Paul Walsh

ORGANIZATION: U. S. Naval Research Laboratory, Washington, D. C.

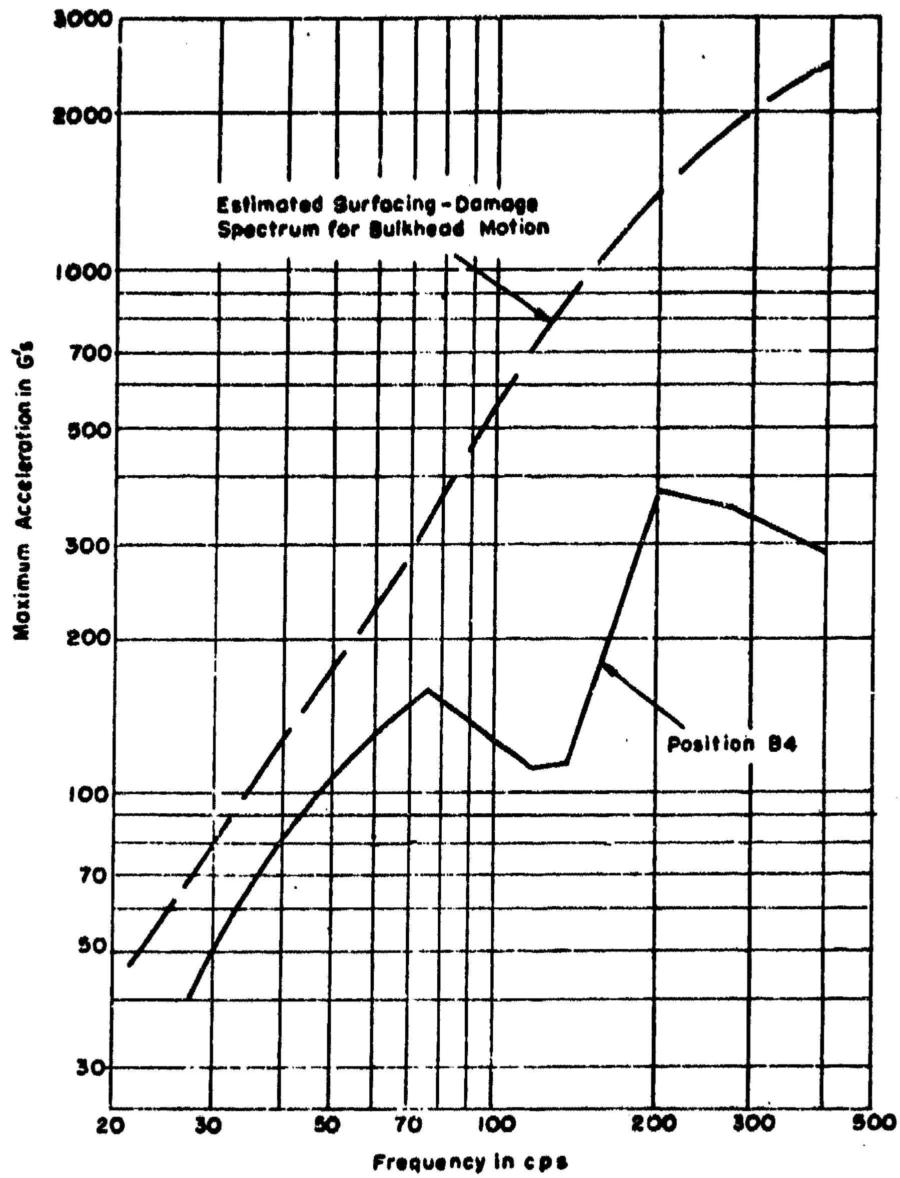

Fig. 3.68—Comparison of shock spectrum from a bulkhead on SQUAW-13 with estimated surfacing-damage shock spectrum for bulkhead motions.

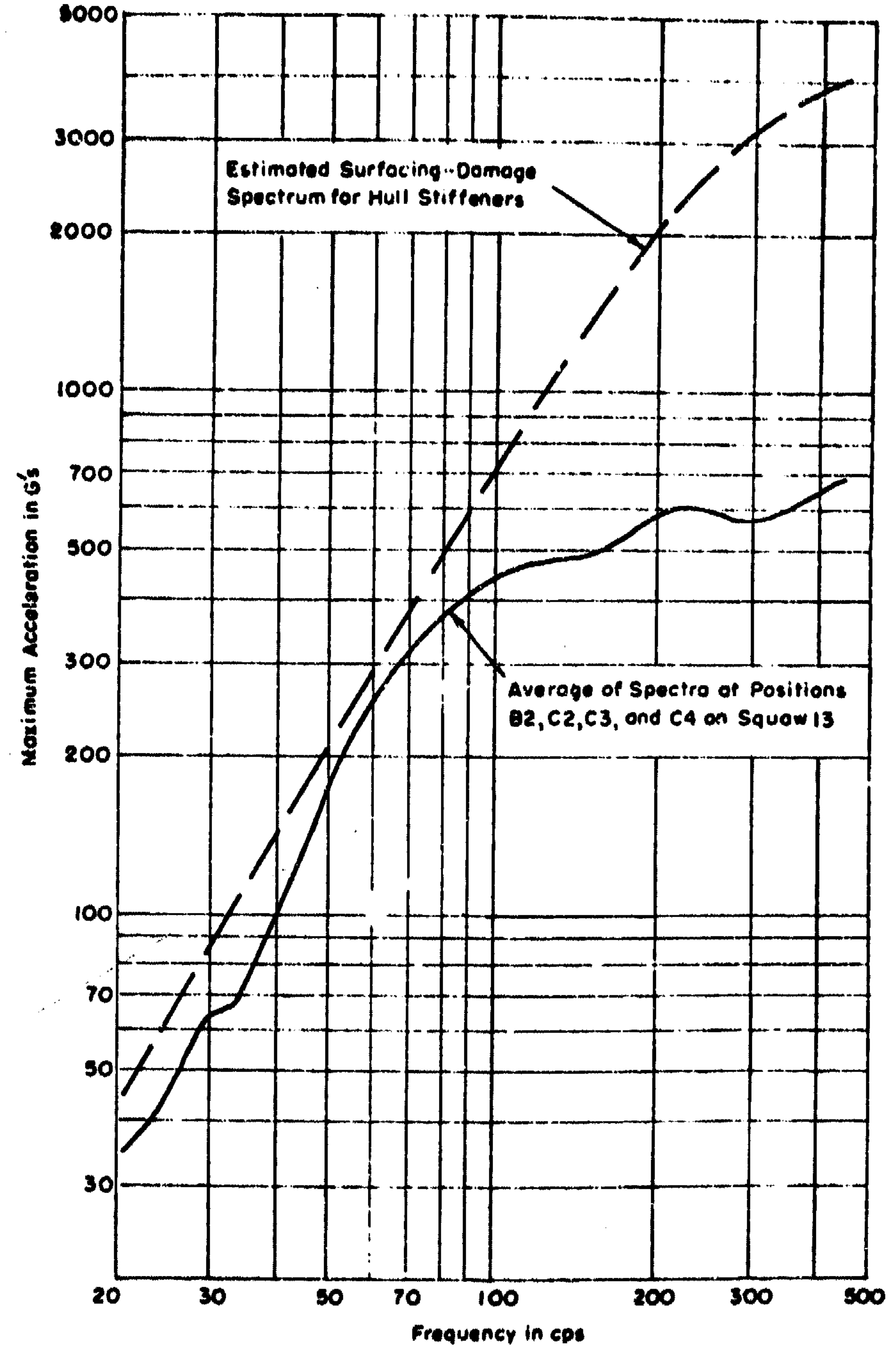

Fig. 3.69—Comparison of average spectrum from hull stiffeners on SQUAW-13 with estimated surfacing-damage shock spectrum for hull-stiffener motion.

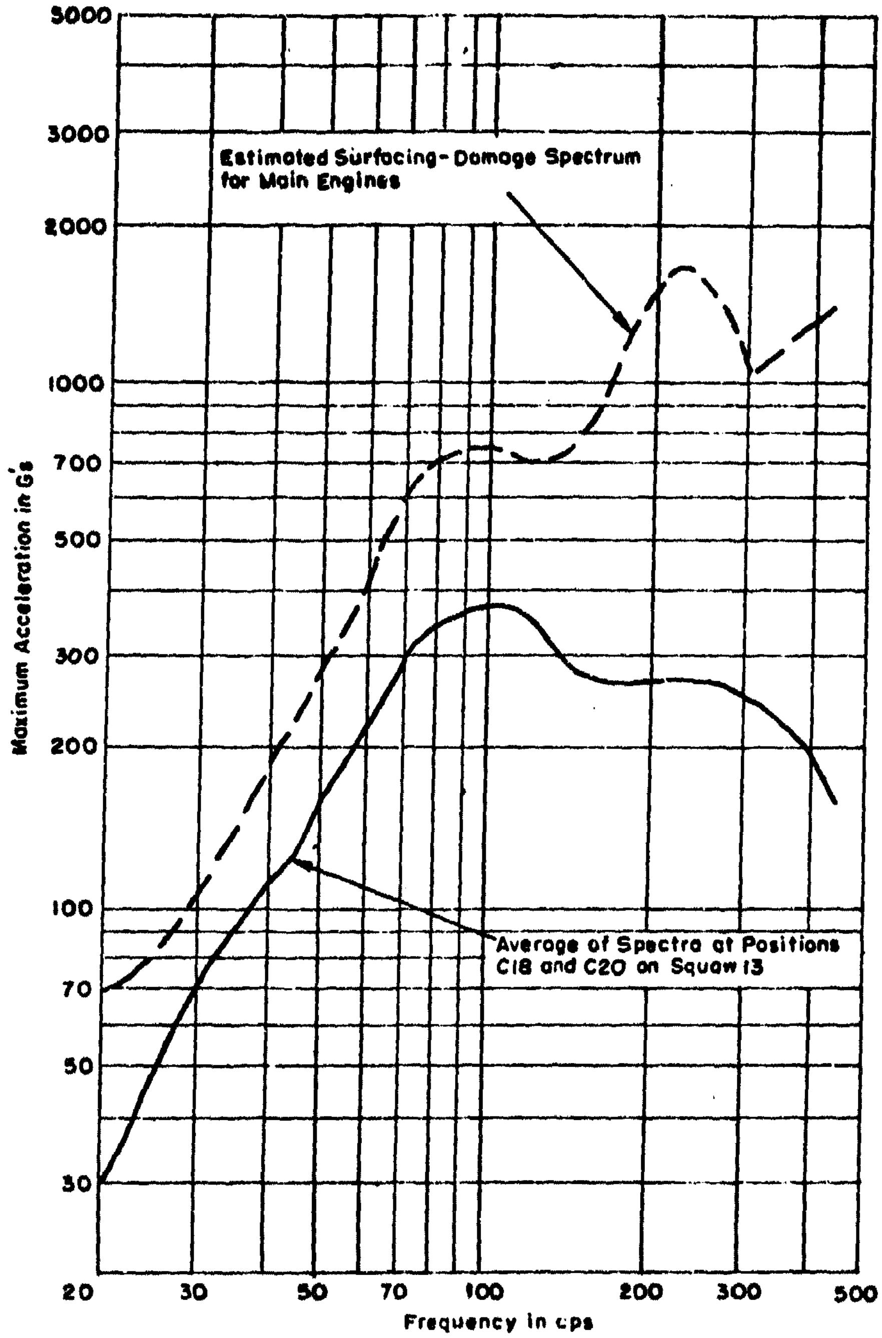

Fig. 3.70—Comparison of average spectrum from simulated main engines on SQUAW-13 with estimated surfacing-damage shock-spectrum motion for main engines.

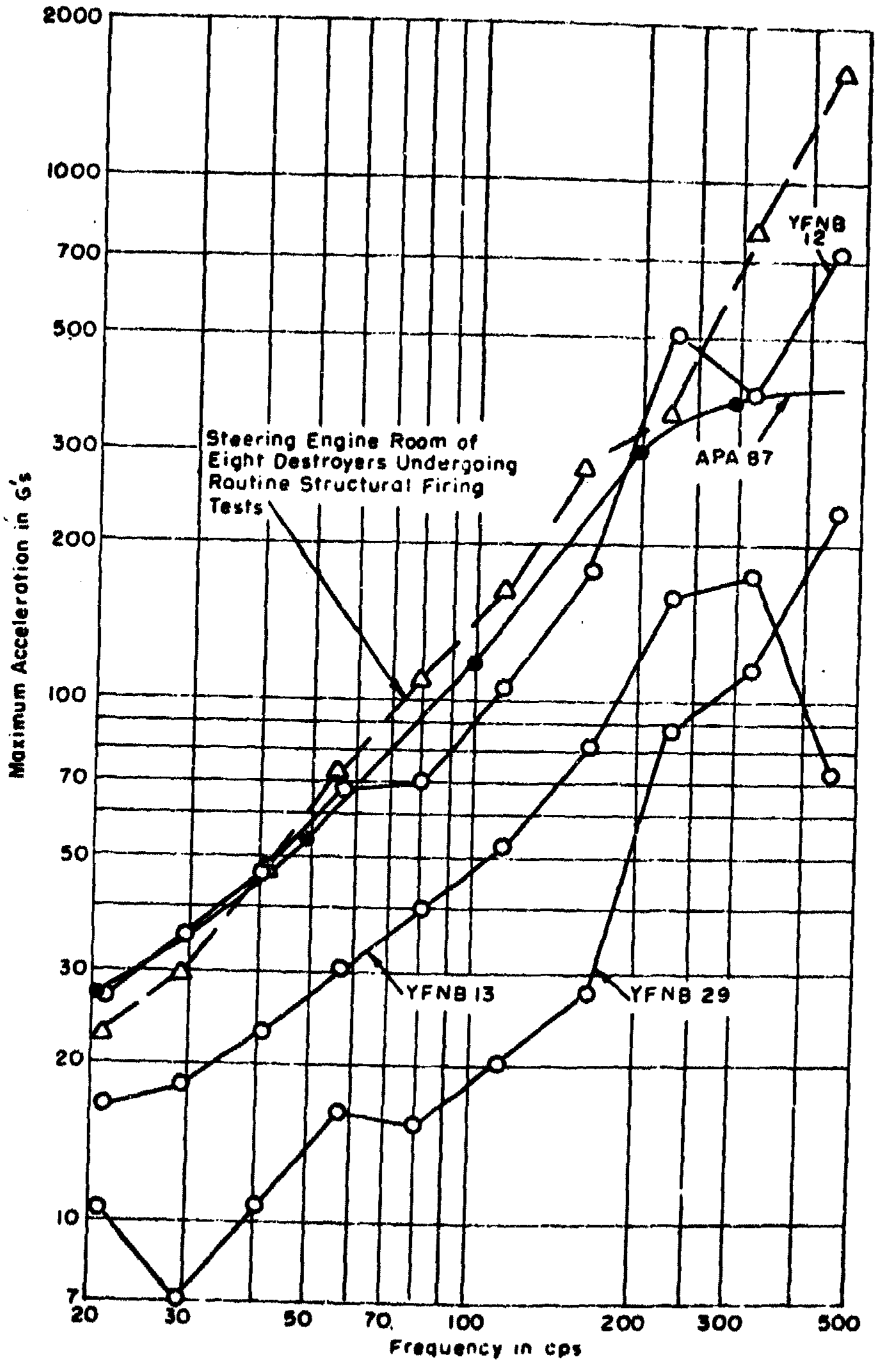

Fig. 3.71—Comparison of average shock spectrum for inner bottoms of three YFNB's with spectra obtained from conventional explosive tests on other surface ships.

1. Objectives

a. Measure the shock motions of the YFNB targets.

b. Develop a method for prediction of shock damage to surface ships caused by a deep atomic explosion.

2. Results

a. The shock severity was more nearly proportional to dome velocity than to shock factor.

b. The shock-spectrum velocities tend to be of the same order of magnitude as the dome velocities.

c. The fact that the data showed consistent deviations from exact proportionality to dome velocity indicates that we do not yet have a firm theoretical explanation of the phenomenon. A qualitative analysis confirmed this view.

d. An important difficulty with the simple dome-velocity theory is that it assumes that draft, beam, heading, region of the bottom, etc., have no influence on shock severity.

3. Recommendations

a. Model tests should be conducted to explore the effect of change in dimensions, heading, and draft of a ship upon shock spectra.

b. Theoretical and experimental studies should be made to extend the qualitative analysis mentioned above.

c. Data should be obtained on full-scale surface ships to show what level of shock spectrum corresponds to severe damage of modern warships in operating condition.

PROJECT 3.3

TITLE: Vibration Characteristics of Certain Items on SQUAW-29; YFNB-29, and PAPOOSE C (Operation Wigwam, WT-1026, Confidential, A. R. Paladino)

PROJECT OFFICER: F. F. Vane

ORGANIZATION: David Taylor Model Basin, Washington, D. C.

1. Objective

Provide instrumentation for, and obtain the vibration characteristics of, the SQUAW, YFNB, and PAPOOSE C (a $1/_{5.33}$-scale model of the SQUAW) targets.

2. Results

a. The complexity of the structures and the necessity of using impact methods of excitation often made identification of the specific frequencies difficult.

b. Frequencies were excited for all items tested on SQUAW-29 and PAPOOSE C.

(1) A few frequencies were excited with a vibration generator for the resiliently mounted equipment on SQUAW-29 and by striking for those on the YFNB-29. Many frequencies were excited for the rigidly mounted center engine and port main motor on SQUAW-29.

(2) Although the force of excitation by striking was applied directly to only one mass of the battery rows, a number of adjacent masses in a row were excited.

(3) A number of frequencies of the bulkheads in transverse modes were excited by striking. A frequency of 113 cycles/sec was obtained for a number of models.

(4) Many frequencies of the hull were excited in attempting to find the frequency of the accordion mode by striking but could not be identified as accordion-mode frequencies since phase differences could not be measured on the records owing to the multifrequency response. However 37 cycles/sec was obtained for a number of models.

(5) The lowest apparent frequencies of a flexural hull mode excited by striking were 9.4 cycles/sec in the athwartship plane and 8.6 cycles/sec in the vertical plane.

c. Tests by striking showed that items responded in numerous frequencies simultaneously. The modes of vibration were identified positively for only some of these frequencies.

d. Some of the SQUAW-29 results were corroborated by those obtained on PAPOOSE C since many of the frequencies obtained on the latter were almost identical with those obtained on SQUAW-29 when converted to full scale. The corroboration between SQUAW-29 and PAPOOSE C indicates the usefulness of checking resonance response of a model prior to construction of a full-scale structure if the desired response of a full-scale structure is critical.

3. Recommendation

A similar study should be made in preparation for similar future tests.

PROJECT 3.4

TITLE: Response of SQUAW Targets from High-speed Motion Pictures of Interior (Operation Wigwam, WT-1027, Confidential, Charles M. Atchison)

PROJECT OFFICER: Harry L. Rich

ORGANIZATION: David Taylor Model Basin, Washington, D. C.

1. Objective

Obtain high-speed motion pictures of the critical portions of the hull and the simulated equipment in the test compartments of each SQUAW target. These films were to show the responses of each target in slow motion and to supply data from which displacements could be plotted as a function of time and analyzed.

2. Results

a. SQUAW-12 and SQUAW-13 equipment was lost with the targets.

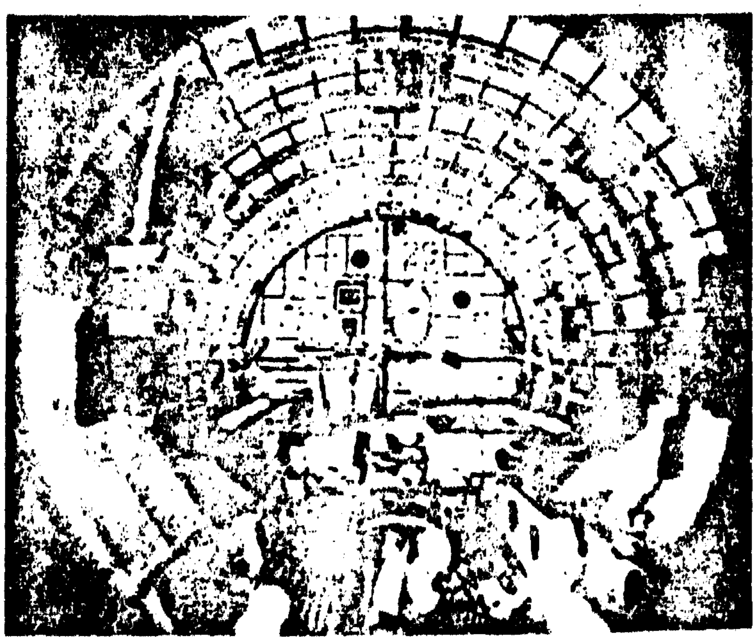

Fig. 3.72—Black-and-white print of frame from color motion pictures taken from position E-5 in the engine room on SQUAW-29. This picture was taken with a Traid camera operating at 200 frames/sec using an 84° wide-angle lens.

b. SQUAW-29 equipment operated satisfactorily (Fig. 3.72). As a typical case, the results obtained on the port engine are presented graphically in Fig. 3.73.

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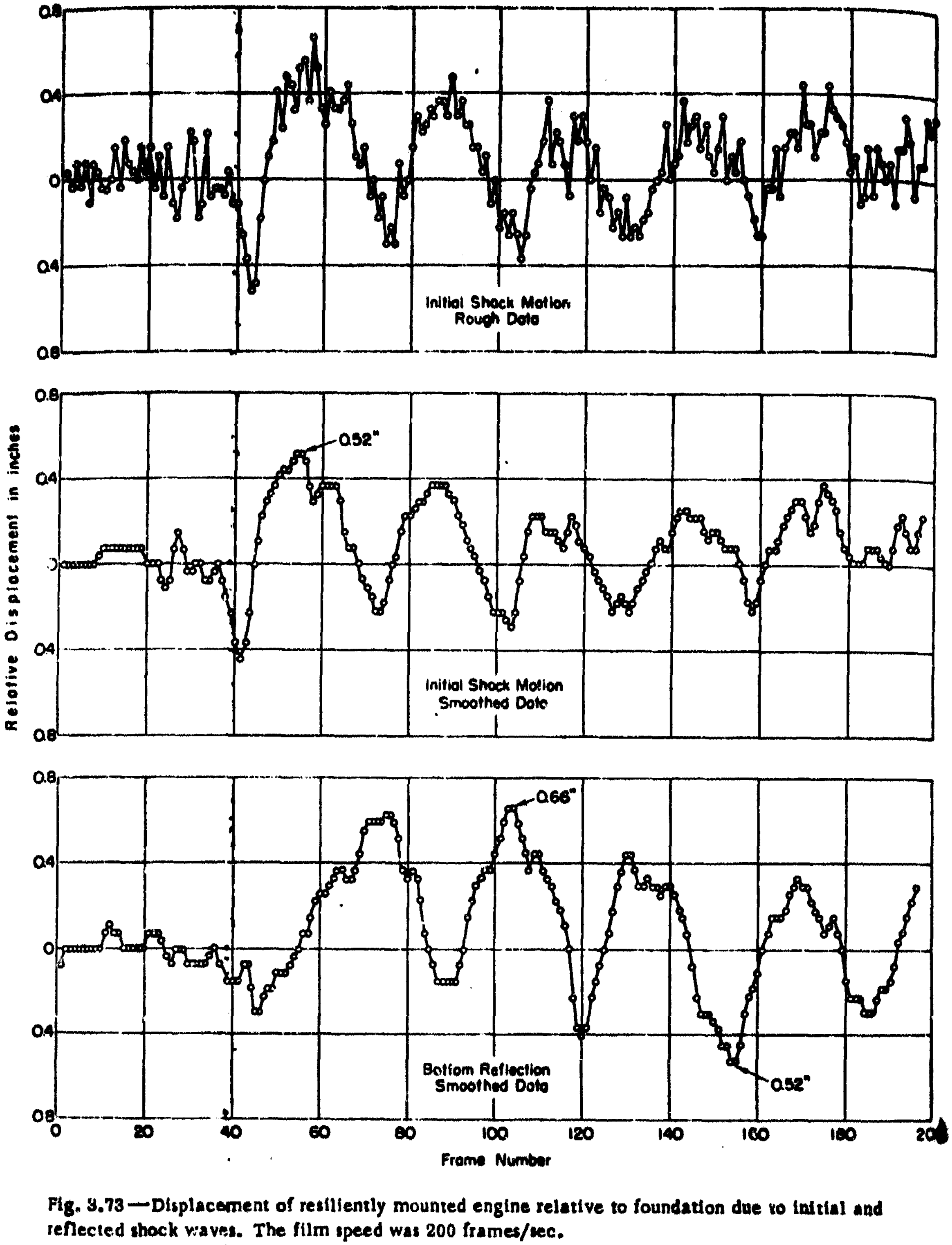

Fig. 3.73—Displacement of resiliently mounted engine relative to foundation due to initial and reflected shock waves. The film speed was 200 frames/sec.

TABLE 3.8—ROLL, PITCH, HEADING, DEPTH, AND FLOODING DATA FOR SQUAW-12

Event	Roll, deg	Pitch,* deg		Depth, ft		Flooding indication							
		First gauge	Second gauge	Fwd cone	After cone	Fwd cone		Battery comp		Eng comp		After cone	
						Low	High	Low	High	Low	High	Low	High
D—1 day													
1100, prior to submergence	10 max	3 max	3 max	0	0	No	No	No	No	No	No	No	No
1130, just after submergence	0	−16	−16	260	220†	No	No	No	No	No	No	No	No
1300, during tow	8 port	−16	−16	260		No	No	No	Yes‡	No	No	No	No
1600, during tow	0	+35	+35	250		No	No	No	Yes	No	No	No	No
D-day													
0600, evacuation	0	+35	+35	250		No	No	No	Yes	No	No	No	No
1300, −15 sec§		+36	+35	255			No		No		No		No
0 time		+36	+35	255			No		No		No		No
+3 sec¶		+15					No		Yes		Yes		No
+6 sec		+35					No		Yes		Yes		No
+9 sec							No		Yes		Yes		No
+11 sec		+14†					No		Yes		Yes		No
+14 sec		+14†					No		Yes		Yes		No
+17 sec		+64†					No		Yes		Yes		No
+20 sec		+58†					No		Yes		Yes		No
+23 sec		+90					Yes		Yes		Yes		No
+25 sec							Yes		Yes		Yes		No
+57 sec							Yes		Yes		Yes		Yes

*Plus sign indicates bow up; minus sign indicates bow down.
†Readings corrected since publication of ITR-1078.
‡This indication of flooding was probably due to a short in the instrumentation cable.
§The following times are accurate to +1, −0 sec.
¶The initial shock wave arrived at SQUAW-12 at +1.1 sec.

3. Recommendation

The photographic methods were satisfactory and should be used on future tests.

PROJECT 3.6

TITLE: Depth, Trim, Heading, and Flooding of Wigwam Targets (Operation Wigwam, WT-1030, Confidential-RD, Raymond E. Converse, Jr.)

PROJECT OFFICER: Harry L. Rich

ORGANIZATION: David Taylor Model Basin, Washington, D. C.

1. Objectives

a. Aid the operational phases of submerging, positioning, and surfacing the targets by providing instrumentation in each target to give remote indications of the depth, the angles of roll and pitch, and the heading relative to the atomic device.

b. Define the target's orientation during and after the attack.

c. Determine flooding and its extent at any time.

2. Results

Orientation and flooding data were obtained for each SQUAW target. SQUAW-13 and SQUAW-29 remained dry after the shock. Table 3.8 gives the complete record for SQUAW-12. Table 3.9 gives the attitudes and conditions of all three SQUAWS at time zero.

TABLE 3.9—ATTITUDE AND CONDITION OF SQUAWS AT "ZERO TIME"

SQUAW	Roll, deg	Pitch, deg	Depth,* ft	Flooding	Relative orientation,† deg
12		36, bow up	290	None	65 ±3
13	1, stbd	3, bow down	265	None	8 ±16
29	4, stbd	2, bow down	At the surface	None	21 ±2

*To the center of the centerline bulkhead.

†The angle between the axis of the SQUAW and the normal to the shock front as determined from the velocity-time records of Project 3.2.

3. Conclusions

The test sections of SQUAW-12 flooded at some time between zero and +3 sec (the minimum time resolution of the system), presumably within the first 10 to 20 msec following the arrival of the shock wave. The bow cone flooded between 20 and 23 sec, and the cables parted at 57 sec, indicating that the SQUAW had dropped 300 to 400 ft in that time.

4. Recommendations

None.

PROJECT 3.8

TITLE: Design and Construction of Wigwam Targets (Operation Wigwam, WT-1031, Confidential, W. J. Ross, Naval Architect, Long Beach Naval Shipyard, Long Beach, Calif.

PROJECT OFFICER: LCDR T. Batcheller, USN

ORGANIZATION: Long Beach Naval Shipyard, Long Beach, Calif.

1. Objectives

a. Contract, design, construct, outfit (less transducer installation), and test for acceptance purposes three submarine type targets.

b. Accomplish detailed design of target towing and support arrangement, modification of the structural pontoons, and initial assembly of rigging equipment for each target.

c. Conduct shipyard submergence to check target trim and ballasting systems.

d. Furnish assistance, upon completion of the operation, in surfacing and docking targets in the Long Beach area.

2. Results

The SQUAWS, as finally designed, consisted of simplified submarine type hulls with the following dimensions:

Length (over-all from nose to stern)	132 ft 2⅝ in.
Length (over-all from nose to guard)	134 ft 7⅜ in.
Breadth (extreme)	20 ft 5⅜ in.
Depth (bottom of outer hull to top of superstructure deck)	18 ft 4¾ in.
Depth (bottom of ballast keel to superstructure deck)	22 ft 11⅛ in.
Pressure (hull length, over-all)	121 ft 6½ in.
Pressure (hull, inside diameter)	14 ft 4¾ in.
Ballast keel:	
Length (over-all)	68 ft 10¾ in.
Bottom of ballast keel to bottom of shell	4 ft 6⅜ in.

There was an inner pressure hull of high-tensile steel (HTS) with inside H-bar frames. The pressure hull had a parallel-middle body 58 ft long divided into two compartments by a watertight transverse bulkhead at midships. The ends were conical with hemispherical special treated steel (STS) heads. A flat at the horizontal axis of each conical end formed a trim tank. Access trunks led into each conical end.

The outer hull formed a series of ballast and free-flooding tanks between the inner and outer hulls. The ballast tanks were open to the sea at the bottom and were vented at the top through salvage hoses connected to a YFNB.

A superstructure deck extended from the after access trunk to some distance forward of the nose of the pressure hull. A catwalk extended aft from this superstructure deck to the stern guard. Fittings for handling and towing were installed on the superstructure, and there was a special fitting for attachment of the instrumentation cables at the forward end. The instrumentation cables pierced the nose of the SQUAW pressure hull and extended some 600 ft to a YFNB.

A heavy stern guard was fitted over the after end of the pressure hull. A ballast keel was fitted under the vessel extending some 68 ft 10¾ in. Weights to simulate the batteries and machinery installed in standard submarines were installed in the pressure hull. The general arrangement is shown in Figs. 3.74 to 3.76. Launching is illustrated in Figs. 3.77 and 3.78. A record was made of design, fabrication, and erection history, including inclining, trim testing, and preliminary operational tests with a YFNB. In addition, the characteristics of the structures, such as curves of form, stability, and weight distribution, were recorded.

PROJECT 3.9

TITLE: Modification and Outfitting of Instrument Barges (Operation Wigwam, WT-1032, Official Use Only, J. N. Shellabarger and A. M. Cargile)

PROJECT OFFICER: J. N. Shellabarger

ORGANIZATION: U. S. Navy Electronics Laboratory, San Diego, Calif.

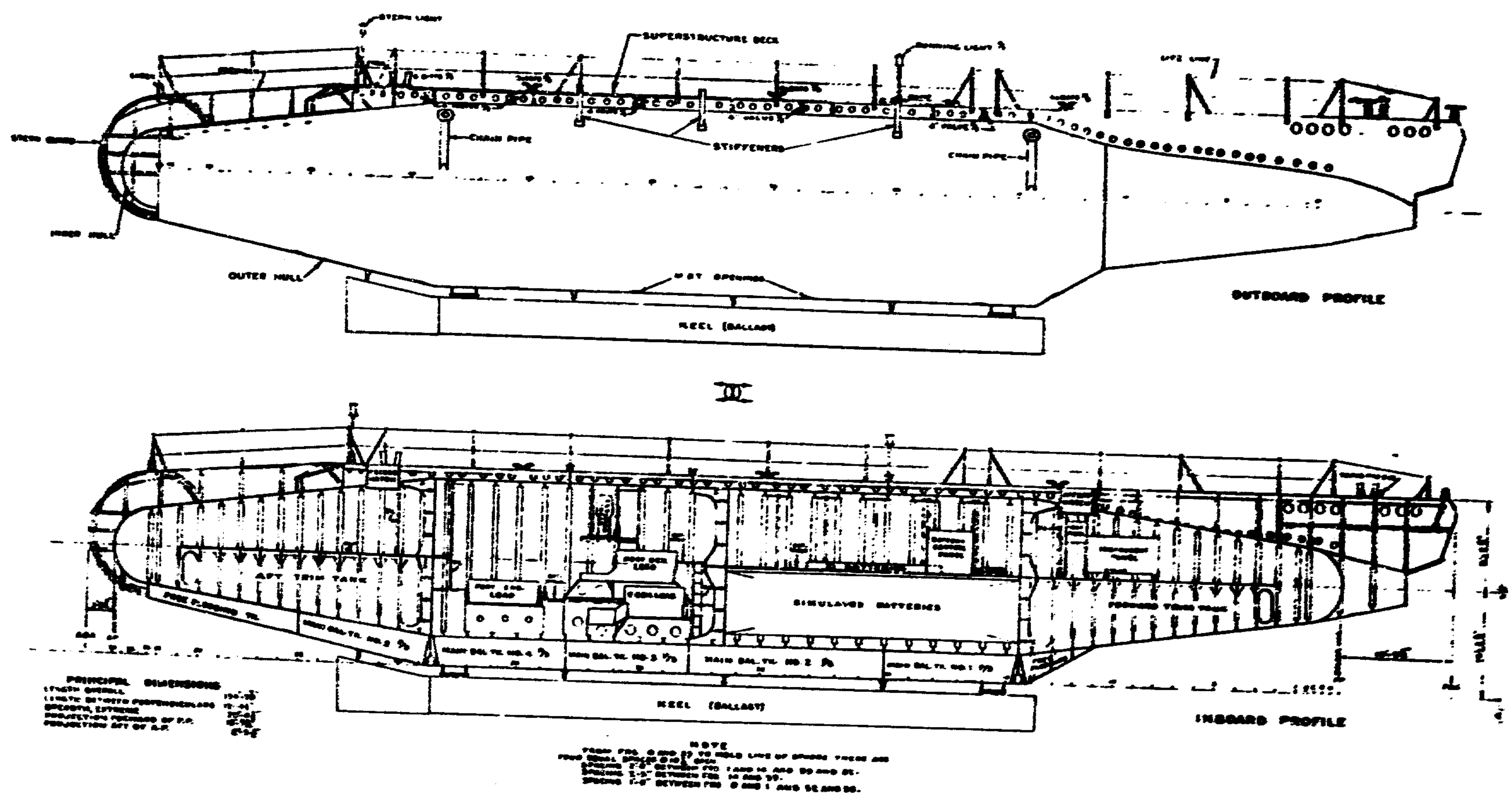

Fig. 3.74—Outboard and inboard profiles of SQUAW.

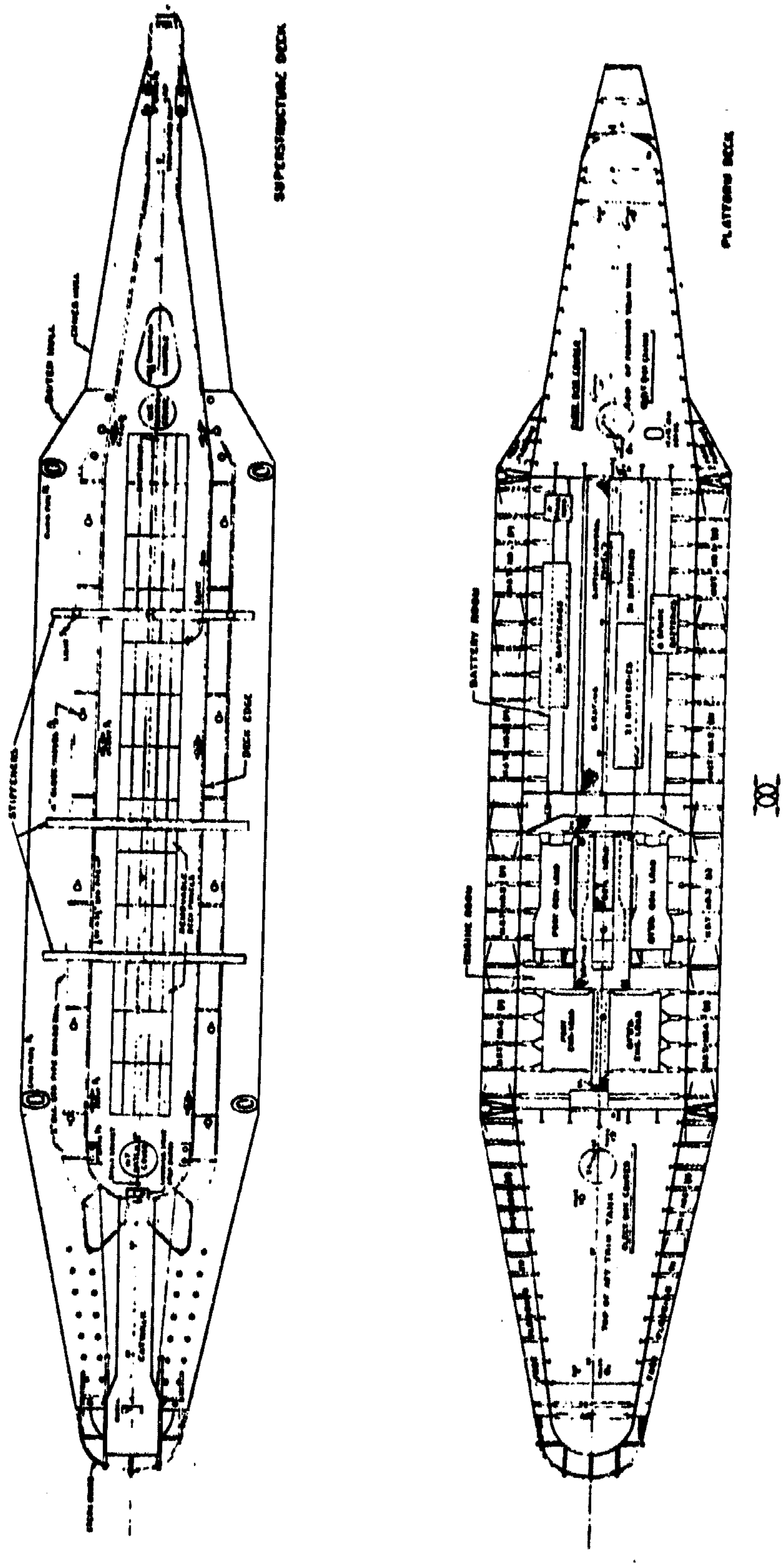

Fig. 3.75—View of SQUAW, showing superstructure and platform decks.

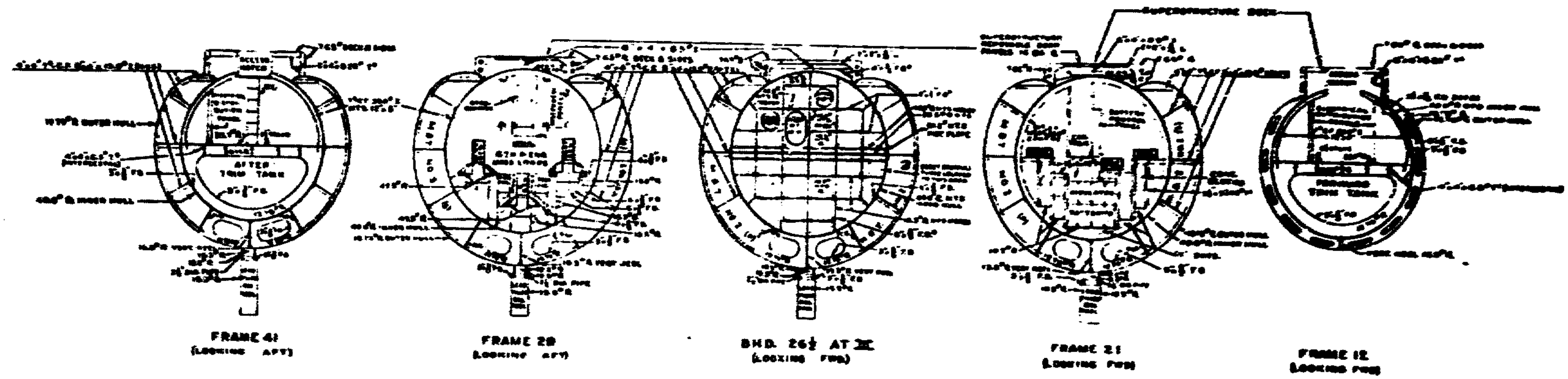

Fig. 3.76 — View of SQUAW, showing midship and type cross sections.

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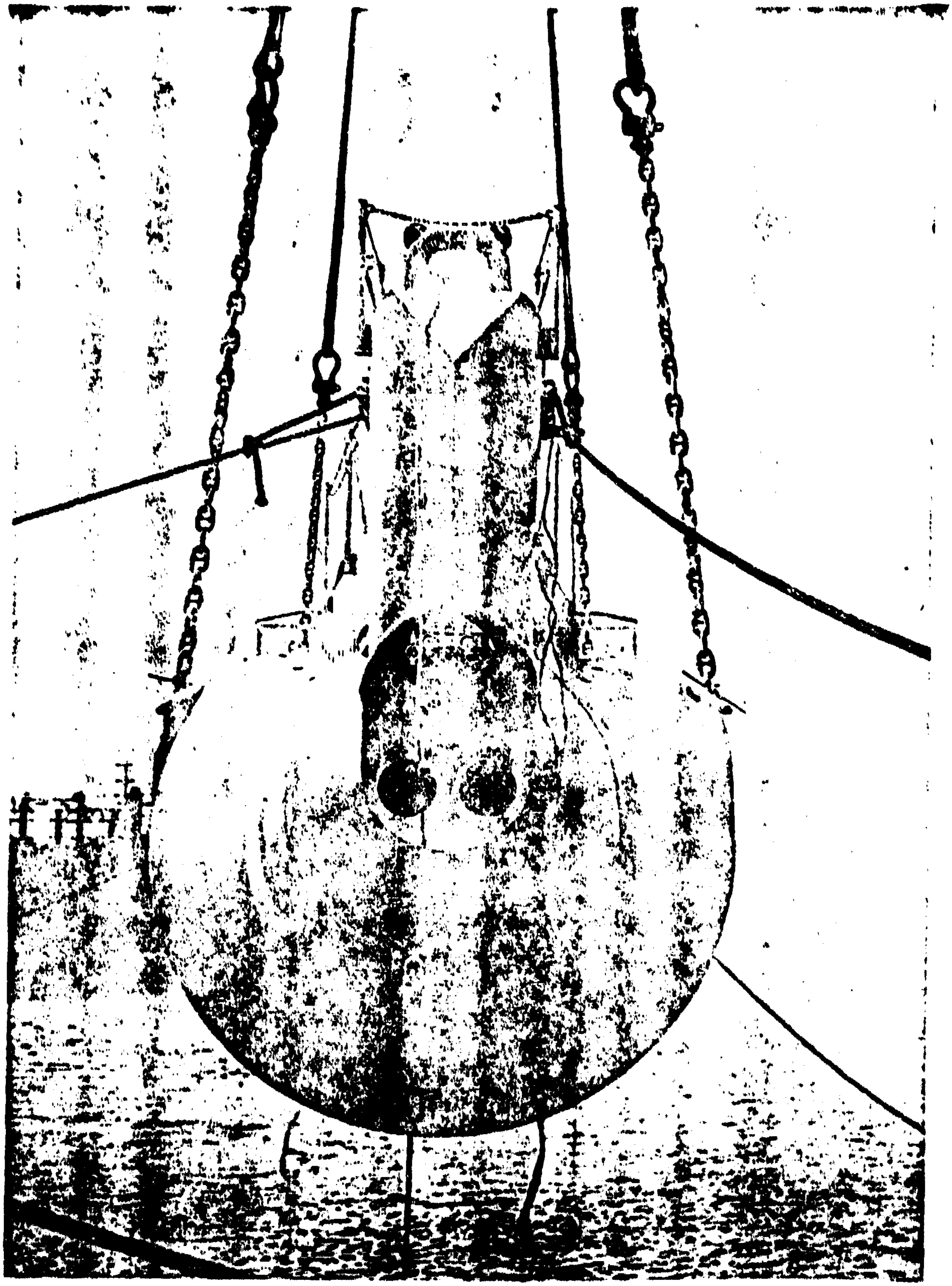

Fig. 3.77—Launching of SQUAW, bow view.

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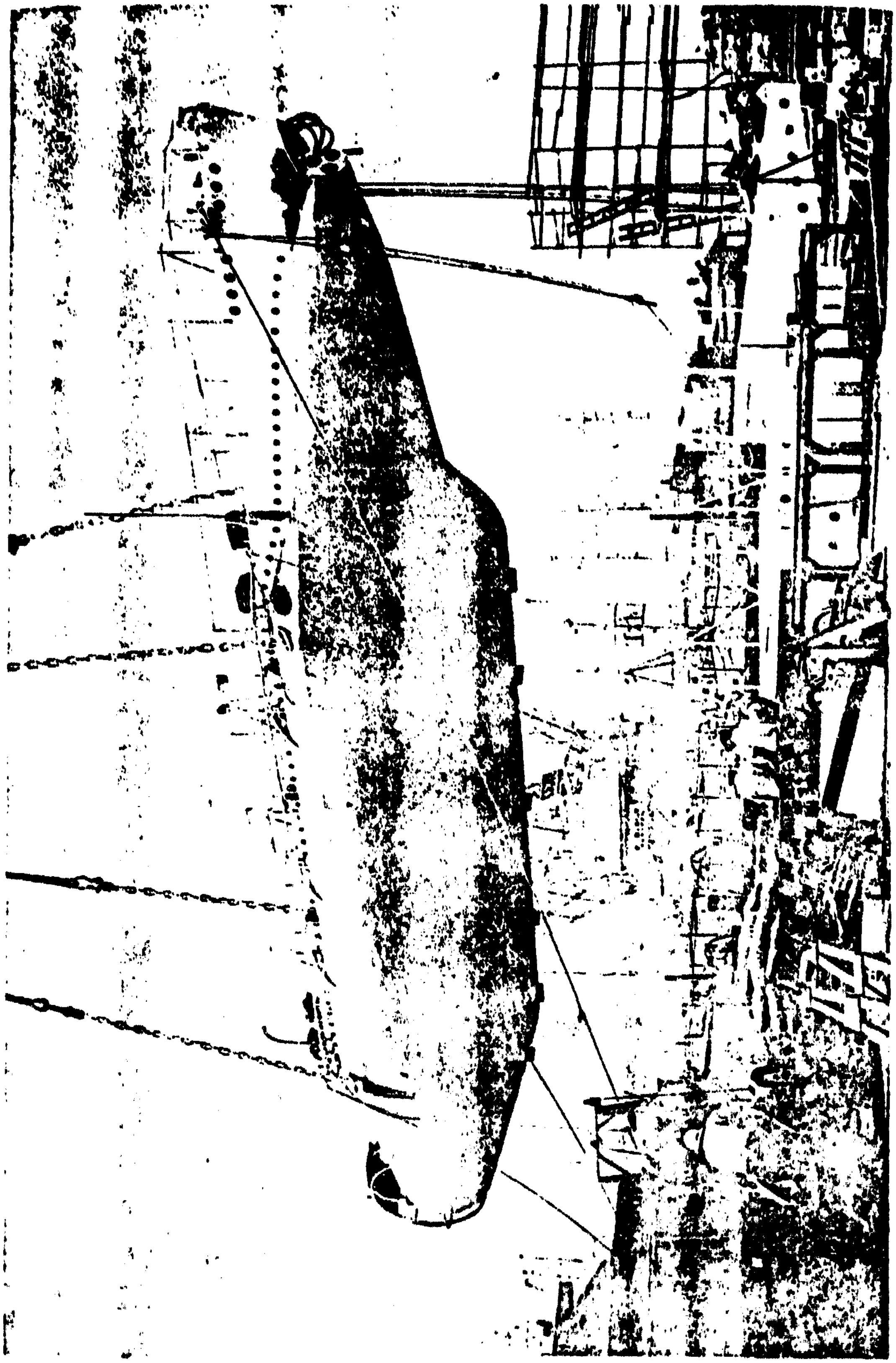

Fig. 3.78—Launching of SQUAW.

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1. Objectives

a. Modify and equip three YFNB barges as surface control stations for the three submersible targets (SQUAWS) constructed under Project 3.8.

b. Provide facilities aboard the three YFNB's to support the remote recording instrumentation associated with these submarine targets under Program III (mostly the responsibility of the David Taylor Model Basin).

c. Support the instrumentation of other scientific projects concerned with experimental work in the vicinity at the barge locations (NOL, NEL, Sandia Corp., NRL, ONR, and EG&G).

2. Results

a. The Project was developed and concluded in two phases. The first phase consisted of major structural modifications and outfitting, ending at initial sea trial of each individual barge. The second phase included minor modifications and additional changes to meet operational requirements, terminating at the January sea trial, at which time the barges were considered to be adequate for the final task. Models of YFNB's are shown in Figs. 3.79 and 3.80, and a time record of the work is given in Fig. 3.81.

b. The barges performed their intended function in the Wigwam array and proved adequate as target control stations and floating bases for instrumentation. During the rather rough sea conditions encountered, the YFNB's were sufficiently stable to remain as effective elements in the array, permitting uninterrupted helicopter service from their landing platforms at times when difficulty was experienced with other array components.

3. Recommendation

Based on this experience, it is recommended that no element smaller than a 100-ft YC barge be used in a Wigwam type array during tests to be conducted on the open sea.

PROJECT 4.1

TITLE: Weapon Placement at Operation Wigwam (Operation Wigwam, WT-1033, Secret-RD, A. K. Billmeyer)

PROJECT OFFICER: A. K. Billmeyer

ORGANIZATION: U. S. Naval Ordnance Test Station, Pasadena Annex, Pasadena, Calif.

1. Objectives

a. Provide technical direction in the procurement of a suitable bomb-support barge and coordinate the bomb-support-barge requirements of the various experimental projects.

b. Provide the bomb case, the main electrical cable system, and the bomb-handling and -supporting system.

c. Provide services for the operation of the barge and the placement of the bomb.

2. Results

The bomb for the actual test (Fig. 3.82) was assembled as a nonnuclear unit into the bomb case aboard the USS Curtiss (AV-4) while it was docked at San Diego (see Project 4.2).

Salt water indicators which would transmit information on leakage to the main firing control center were installed in the bomb case at this time.

The nonnuclear unit was transferred to the Zero Barge on the morning of the barge's departure from San Diego harbor and was transported to the firing site aboard the barge.

Heavy seas and high winds made the Zero Barge an uninviting retreat as D-day approached; nevertheless, 28 persons representing the various interested projects kept vigil aboard the barge during the night preceding the explosion.

Nuclear arming of the bomb and final sealing of the cased unit began at about 0200 on D-day. Lowering operations of the bomb began about 0530. The final lowering operation was handicapped by the heavy sea condition. Constant vigilance was necessary to prevent the main electrical cable from being crushed by the swaying support wire rope as the unit was lowered. Figure 3.83 is a photograph of the barge during the final stage of the lowering operation on D-day.

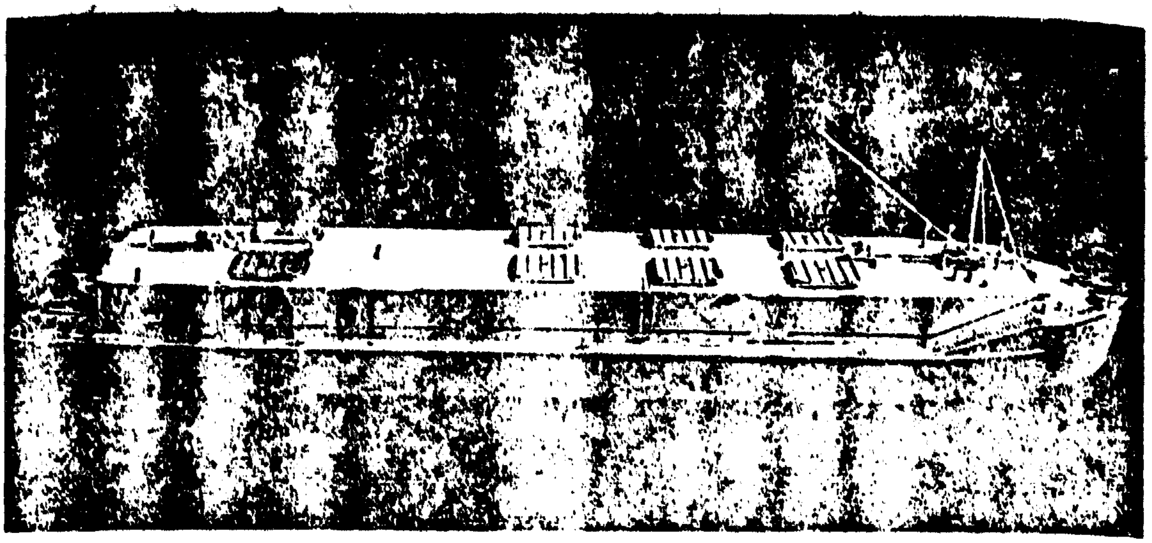

Fig. 3.79—Model of YFNB.

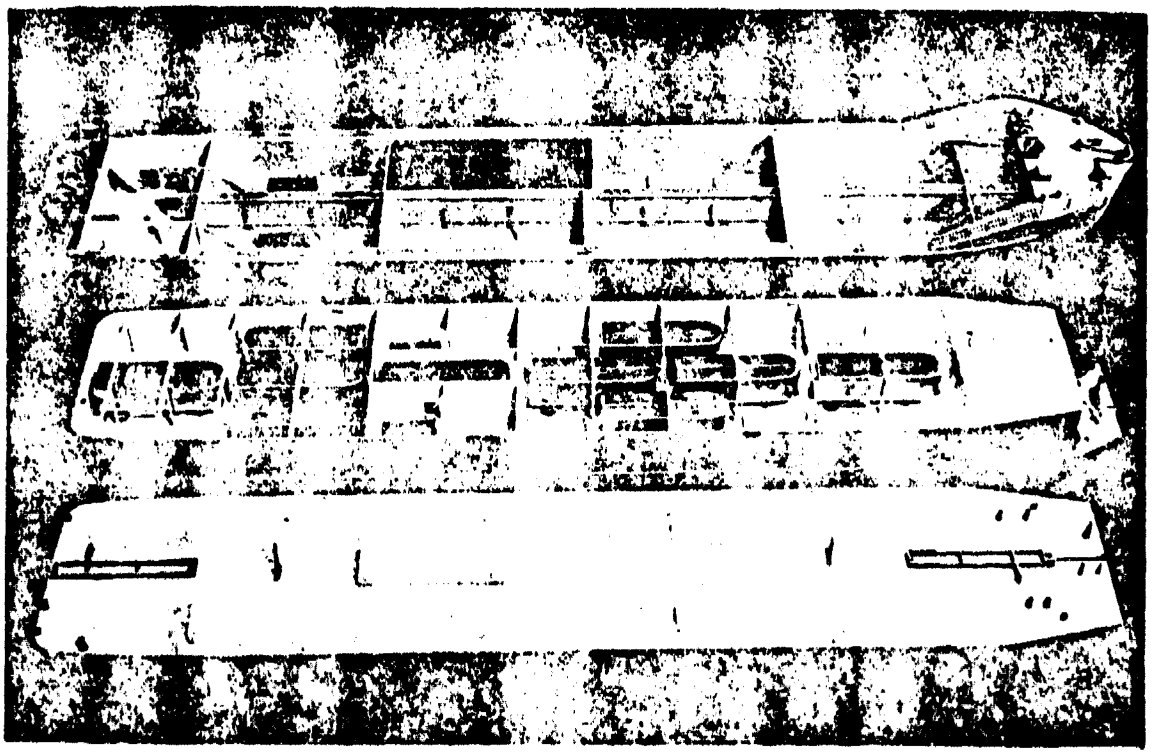

Fig. 3.80—Model of YFNB.

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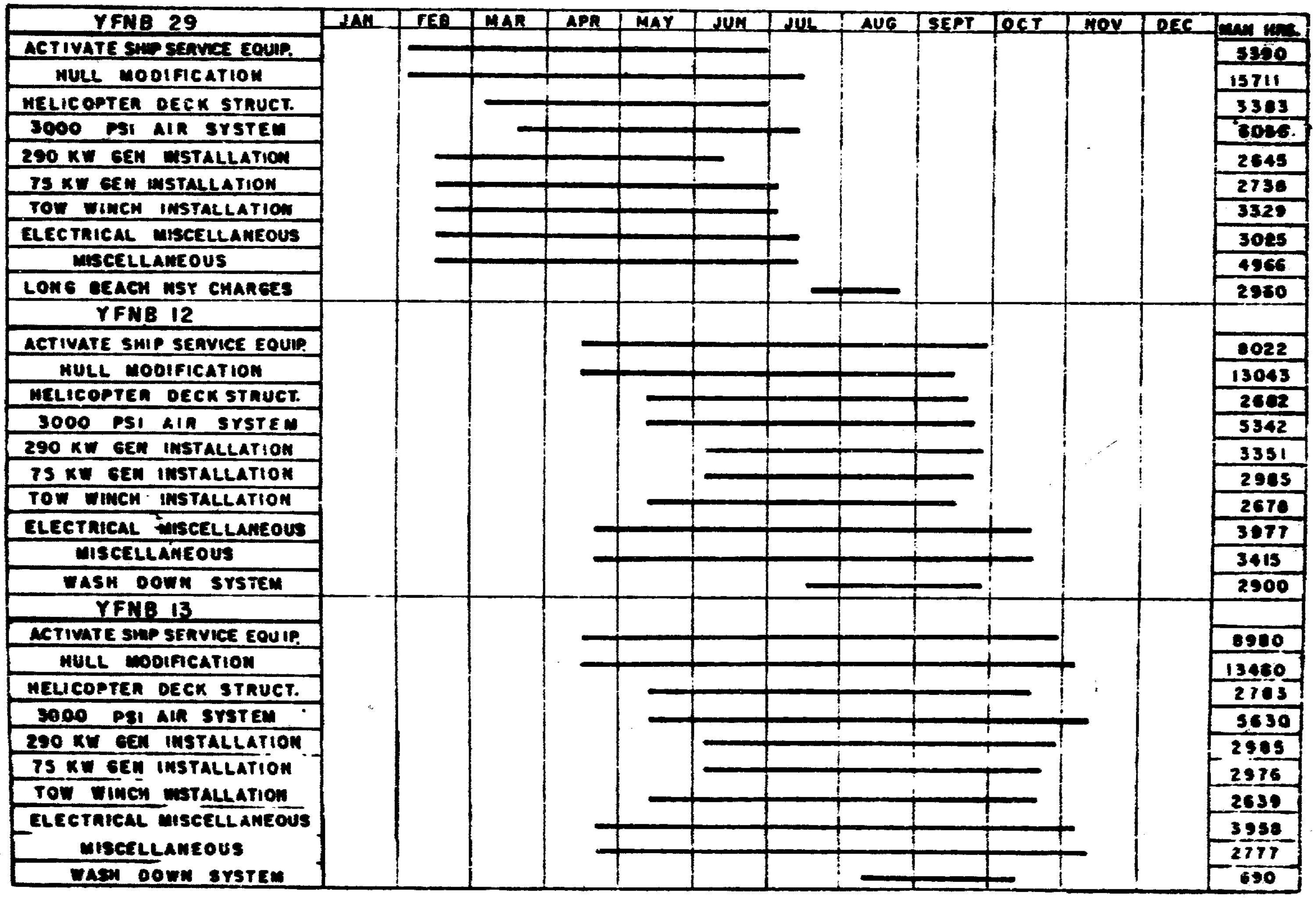

Fig. 3.81—Progress chart on modification of YFNB's.

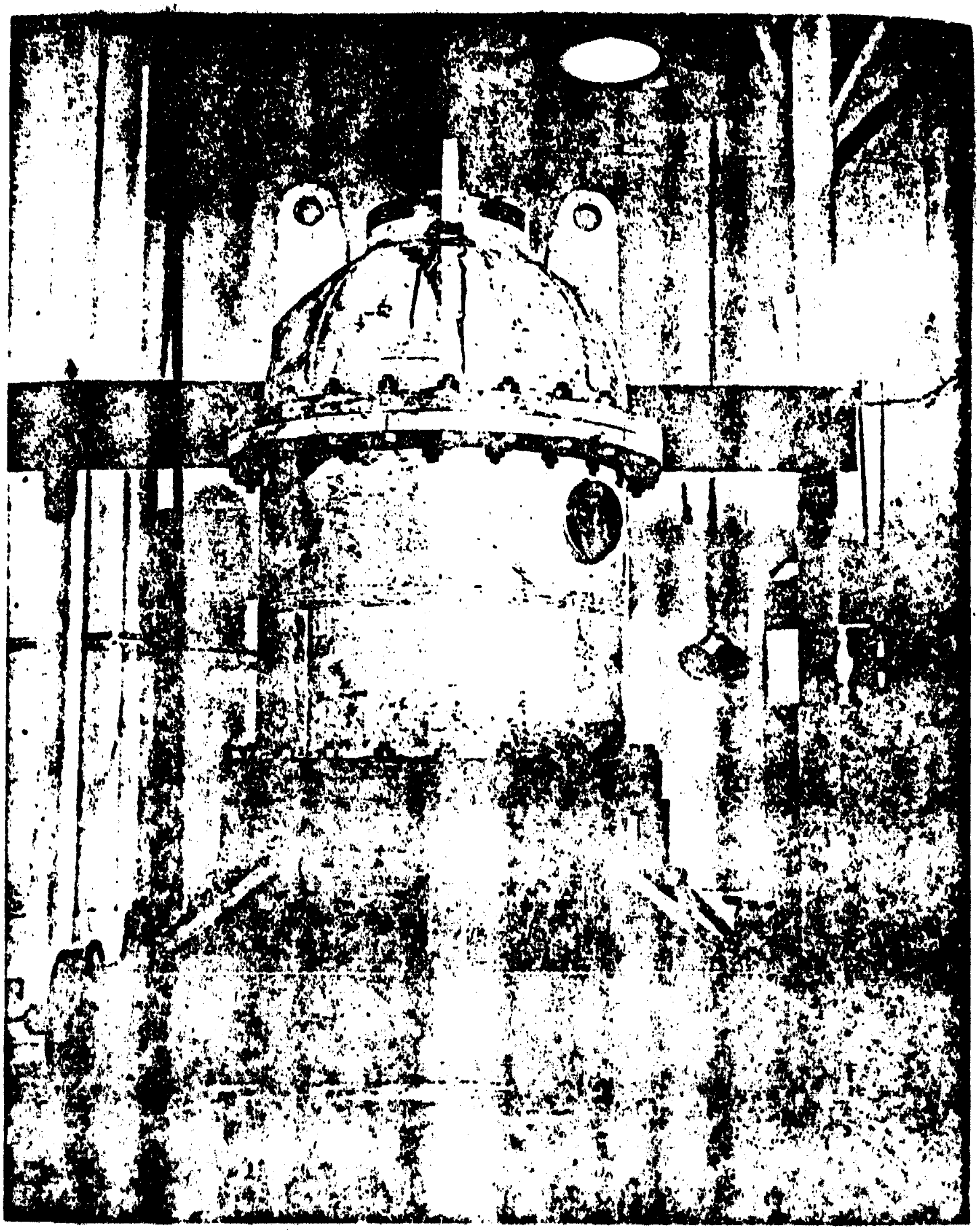

Fig. 3.82—Bomb case on dolly in Zero-barge assembly room.

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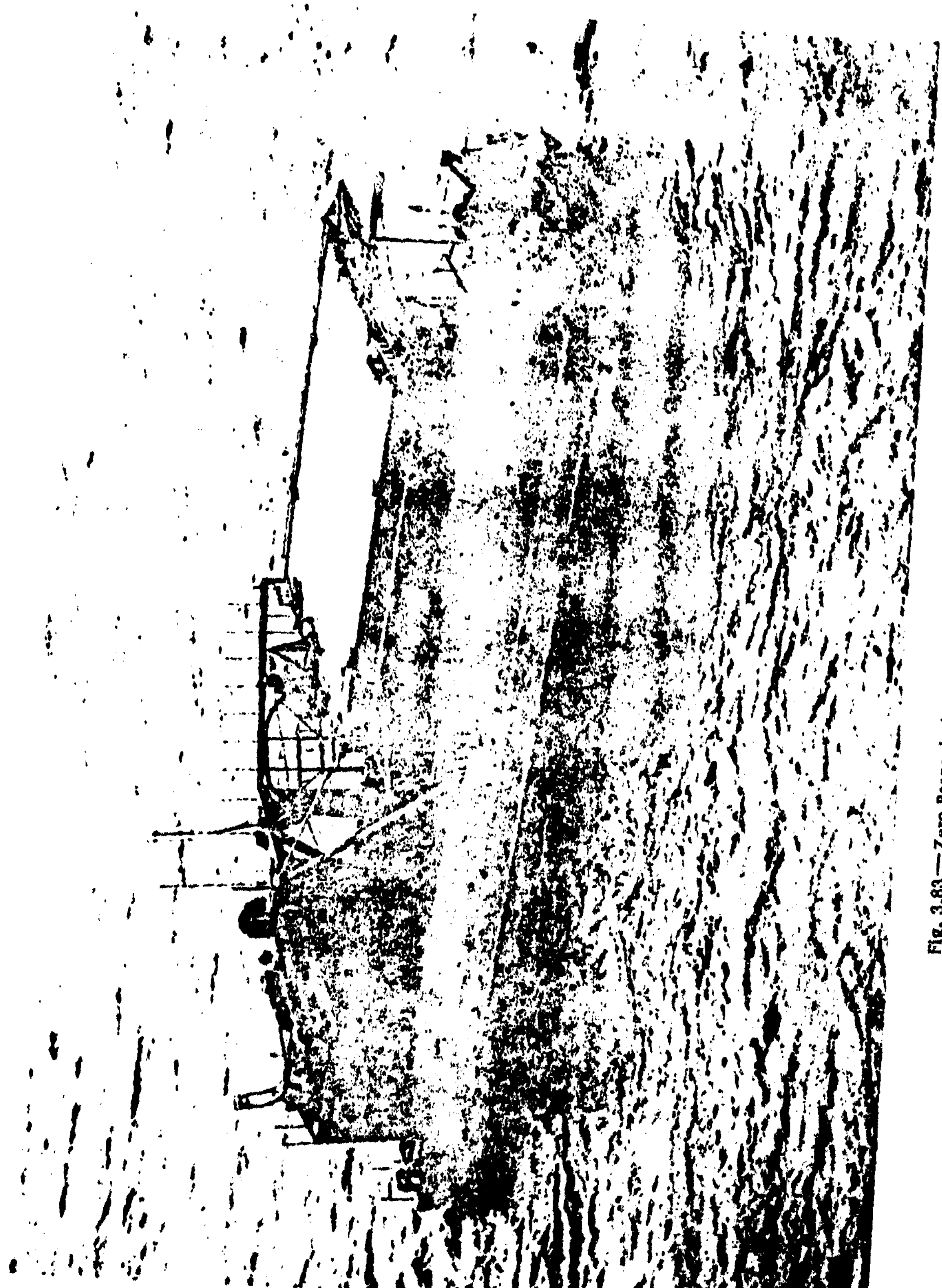

Fig. 3.83—Zero Barge during lowering operation, about H−4 hr.

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The unit was submerged to the 2000-ft depth and secured there at about 1000 (H − 3 hr). All personnel except the four-man firing party were then evacuated from the barge. The firing party left the barge at about H − 2 hr.

The salt water indicators revealed that the inside of the case was dry until the bomb was fired.

At 19 hr 59 min 59.888 ± 0.005 sec GMT on 14 May 1955 the suspended bomb was exploded, and the Zero Barge disappeared from view.

PROJECT 4.2

TITLE: Weapons Assembly (Operation Wigwam, WT-1040, Secret-RD, H. S. North)

PROJECT OFFICER: H. S. North

ORGANIZATION: Sandia Corporation, Sandia Base, Albuquerque, N. Mex.

1. Objectives

a. Procure, assemble, and arm the required weapon in the watertight case provided by Project 4.1.

b. Supervise its placement at deep submergence in such a manner as to insure a successful detonation.

2. Results

A [redacted] warhead [redacted] was provided. This was fired with an [redacted] X-unit. Minor modifications were required to the IFI to accommodate the lower end of the sea cable.

Success of the project was indicated by the weapon's detonation as anticipated.

PROJECT 4.3

TITLE: Radiochemical Determination of Yield (Operation Wigwam, WT-1041, Secret-RD, Dr. R. W. Spence and Charles I. Browne)

PROJECT OFFICER: Dr. R. W. Spence

ORGANIZATION: Los Alamos Scientific Laboratory, Los Alamos, N. Mex.

1. Objective

Determine the fission yield of the weapon used by radiochemical analyses of radioactive water samples provided by Project 2.1.

PROJECT 4.4

TITLE: Close-in Time of Arrival of Underwater Shock Wave (Operation Wigwam, WT-1034, Secret-RD, Francis B. Porzel)

PROJECT OFFICER: Francis B. Porzel

ORGANIZATION: Armour Research Foundation of the Illinois Institute of Technology, Chicago, Ill.

1. Objectives

Measure the close-in time of arrival of the shock, at distances where the shock is strong enough to be effectively supersonic. From the primary measurements, deduce the peak pressure, shock velocity, material velocity, and other peak hydrodynamic variables at the shock front. The nature of the experiment made complementary measurement systems desirable; this was accomplished by use of two similar but overlapping measurements of the time of arrival.

2. Results

The close-in time of arrival of the shock wave from the underwater nuclear explosion of Operation Wigwam was measured with good agreement between duplicate systems of electrical switches activated by shock pressure (Fig. 3.84). The measurements extended from 15 to 2000 ft from the bomb, over a velocity range from approximately 130,000 ft/sec down to acoustic velocities of about 5000 ft/sec. Based on these measurements, the corresponding pressure-distance curve covers a range of 10^5-fold from approximately 10^8 psi down to 3×10^3 psi. These data were used to calculate the peak hydrodynamic variables at the shock front which, in turn, permitted a fairly complete description of the hydrodynamic variables on the interior of the wave (Figs. 3.85 to 3.88). With this knowledge of the wave forms, the weapon yield was calculated to be 31.7 ± 1.2 kt (Fig. 3.89).

3. Recommendation

Similar measurements should be made on future similar operations.

PROJECT 4.5

TITLE: Air Pressures from a Deep Underwater Burst (Operation Wigwam, WT-1035, Secret-RD, M. L. Merritt)

PROJECT OFFICER: J. H. Scott

ORGANIZATION: Sandia Corporation, Sandia Base, Albuquerque, N. Mex.

1. Objectives

Measure air pressures from the deep underwater nuclear explosion at the surface and at altitudes approaching those which would be used by a delivery aircraft. In particular, it was desired:

a. To determine the coupling of the water and the air shock.

b. To determine the attenuation of the shock wave with altitude.

2. Results

Principally because of bad weather, only a few data were obtained (Fig. 3.90). These data, considered with theory and with high-explosive data, led to the following conclusions and recommendations.

3. Conclusions

a. The coupling of peak overpressures of water and air shock waves can be described acoustically. Subsequent behavior cannot.

b. Propagation of the overpressure wave in air away from the surface cannot be described acoustically.

4. Recommendations

a. For planning purposes, we recommend using overpressures in air scaled from WES data as presented in Fig. 3.91.

b. If any further underwater bursts are made, we recommend measuring air pressures from them, but not by using balloons unless better guarantees can be given about weather than at Wigwam. Particularly, pressure measurements should be made if relatively shallow bursts are contemplated.

(Text continues on page 166.)

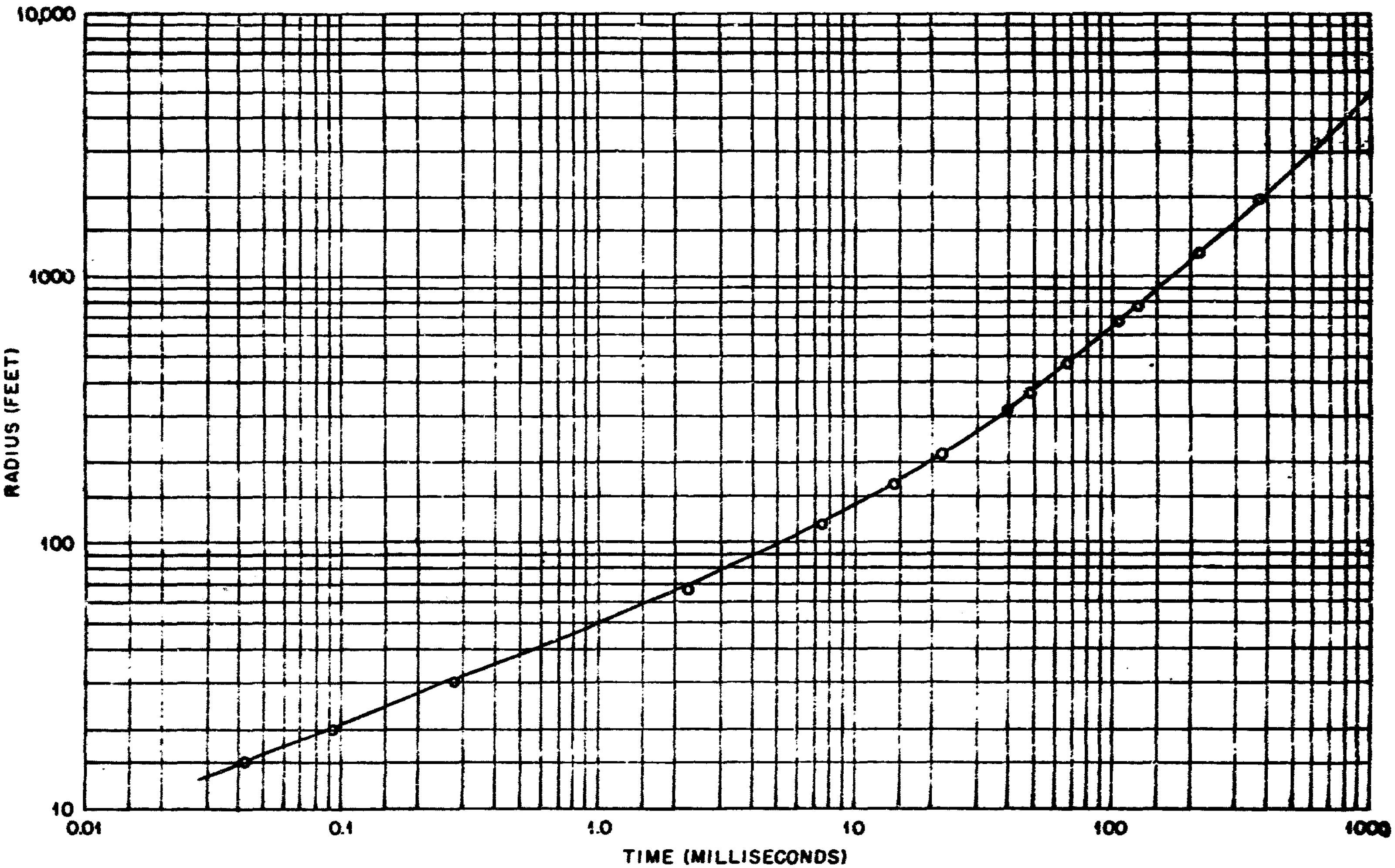


Fig. 3.34—Close-in time of arrival: comparison between theory and test data. O, test data. —, theory.

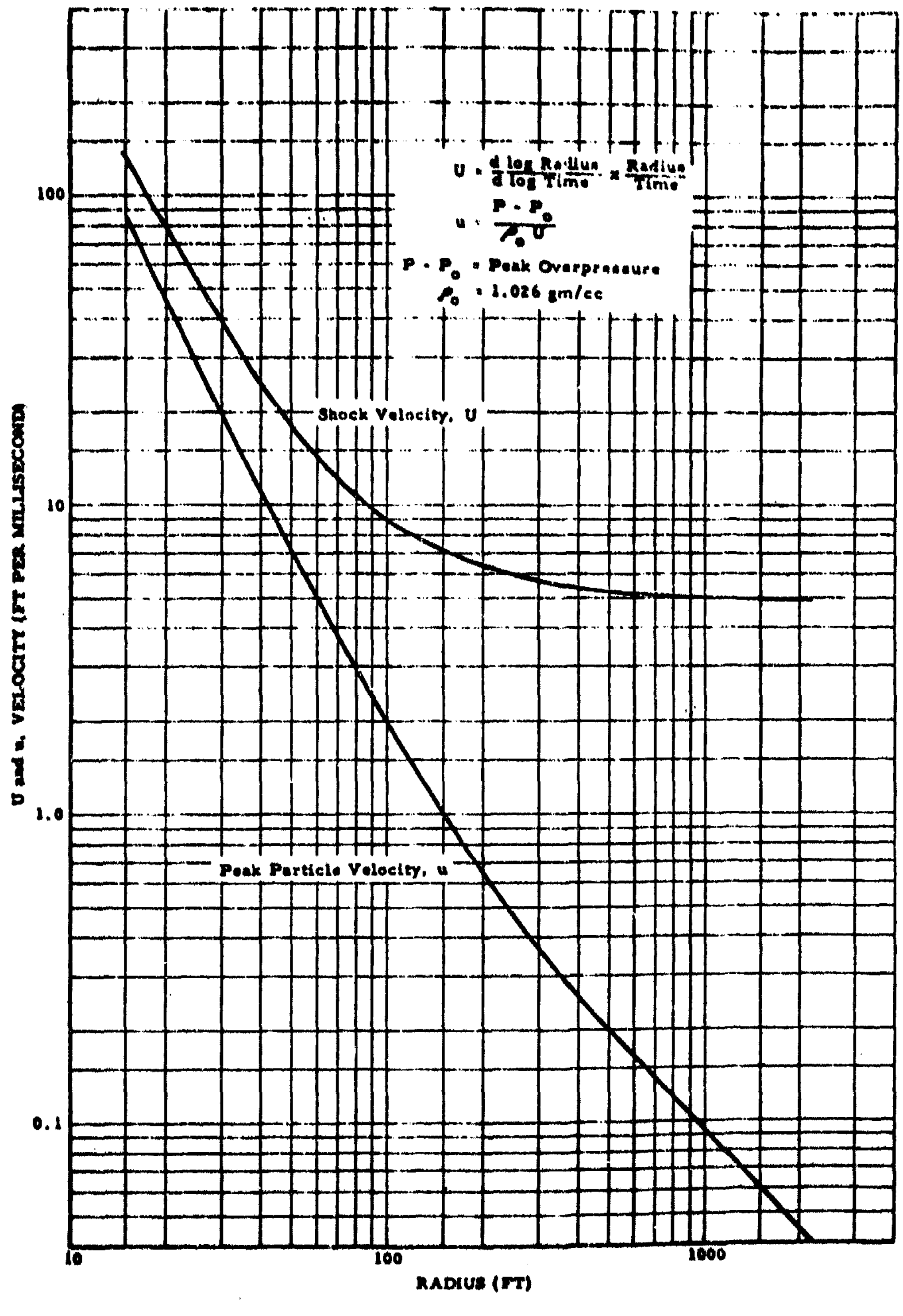


Fig. 3.85—Shock and peak particle velocity vs radius.

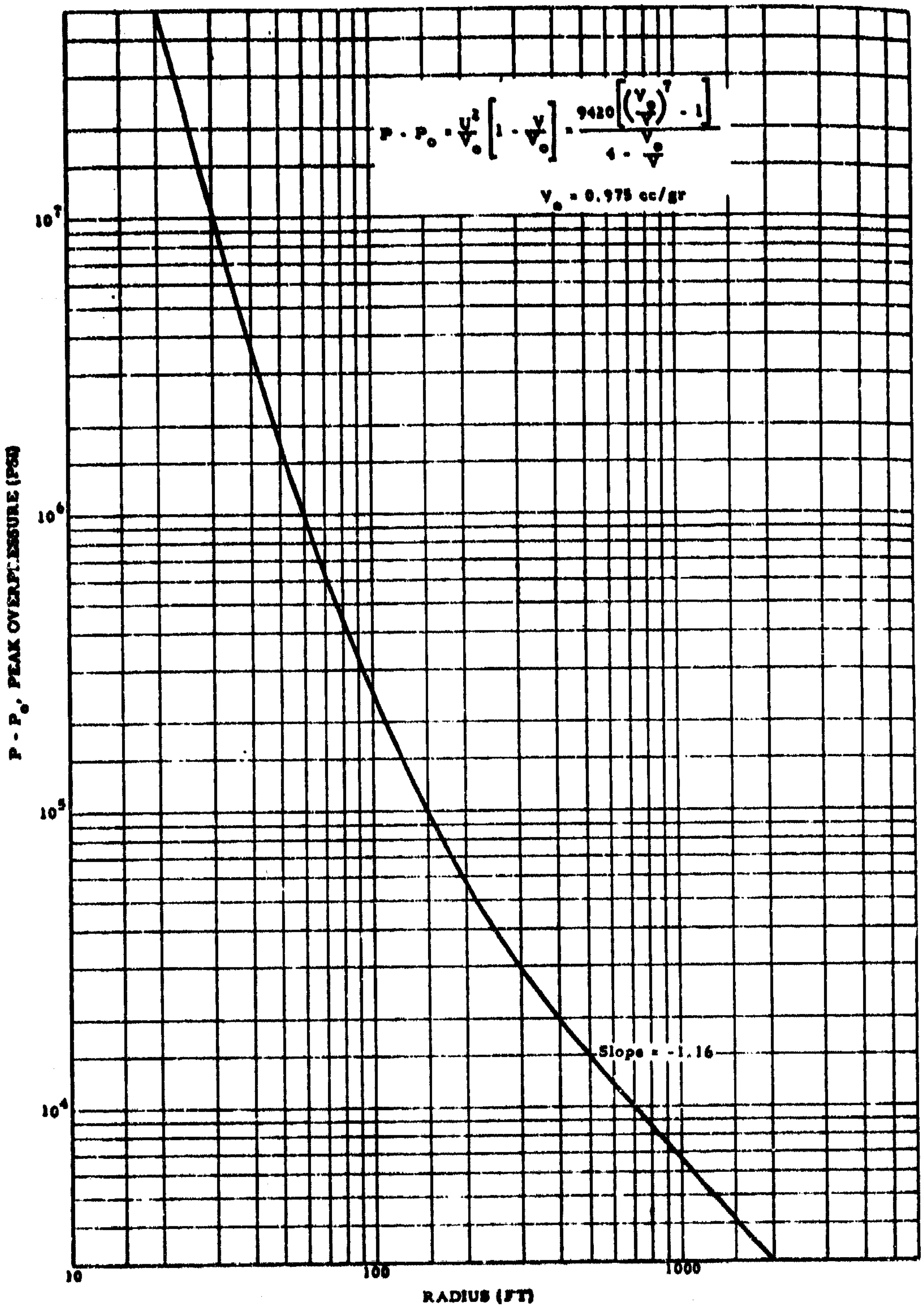


Fig. 3.86—Peak overpressure vs radius.

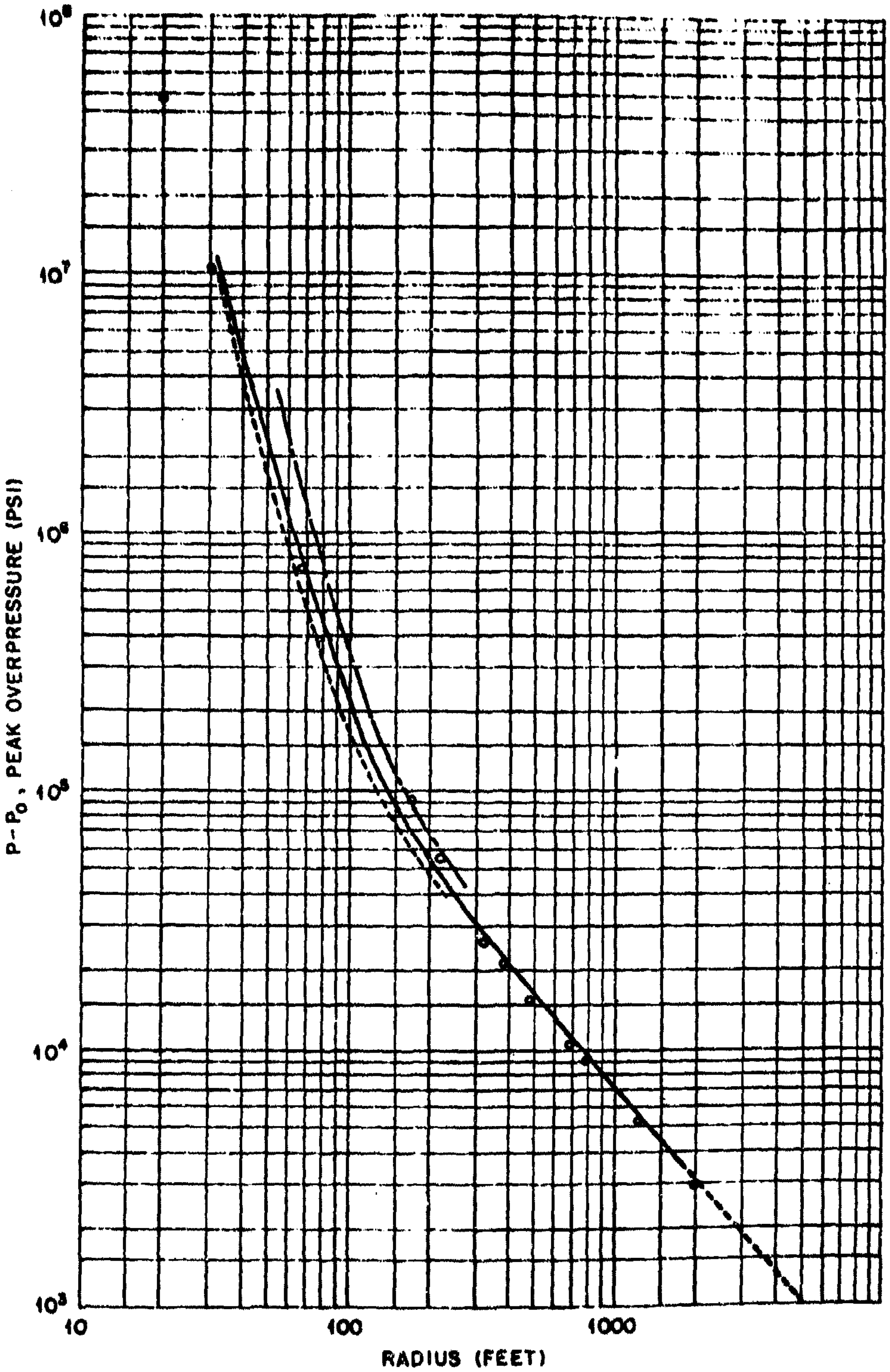


Fig. 3.87—Peak overpressure vs distance: comparison between theory and test data. O, test data at pressure switch locations. —, theory. - - -, lower limit, maximum dissociation. ———, upper limit (no dissociation).

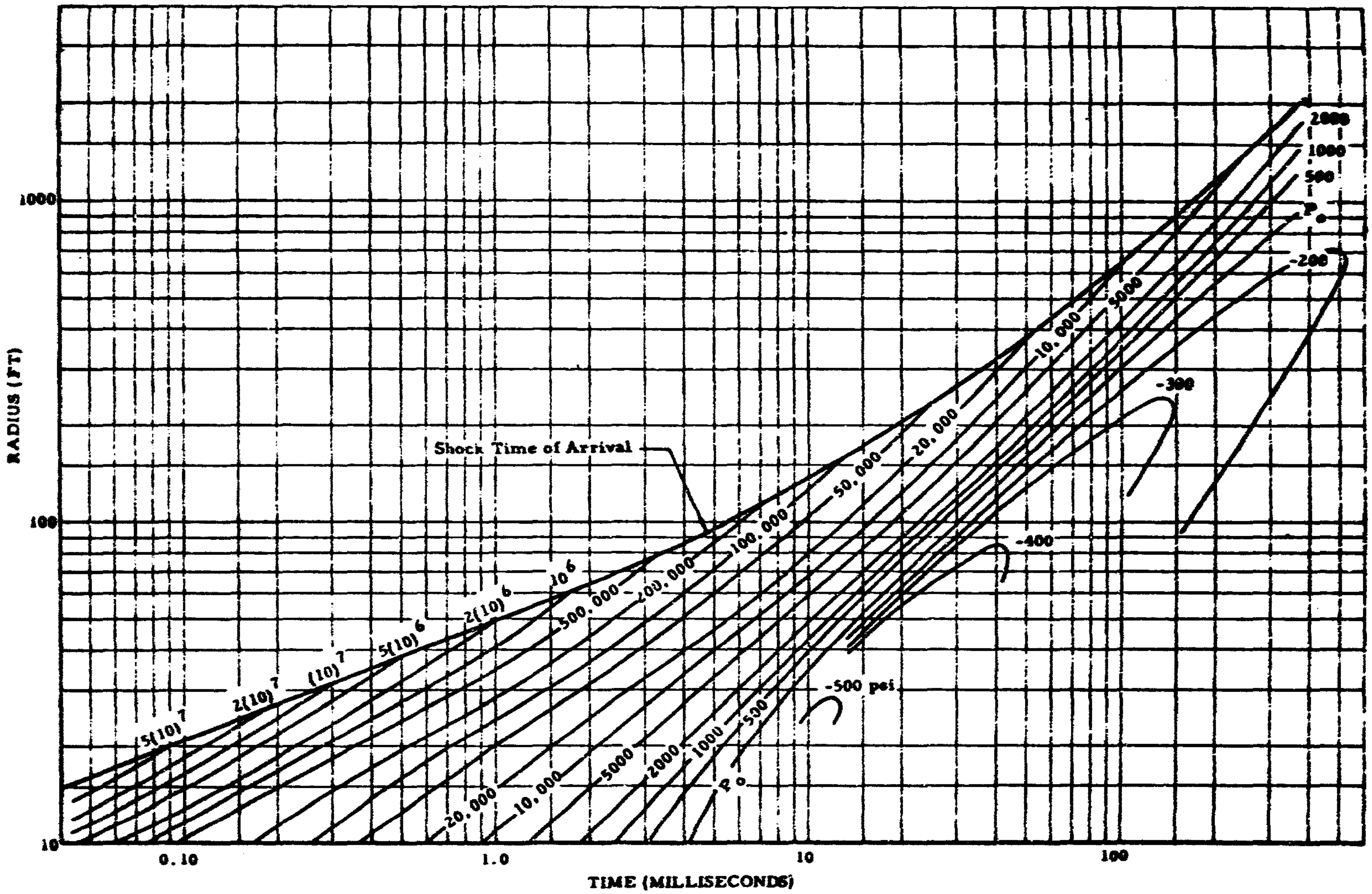


Fig. 3.88—$P-P_0$, overpressure in psi, vs space and time at a depth of 2000 ft (P_0 = 870 psia).

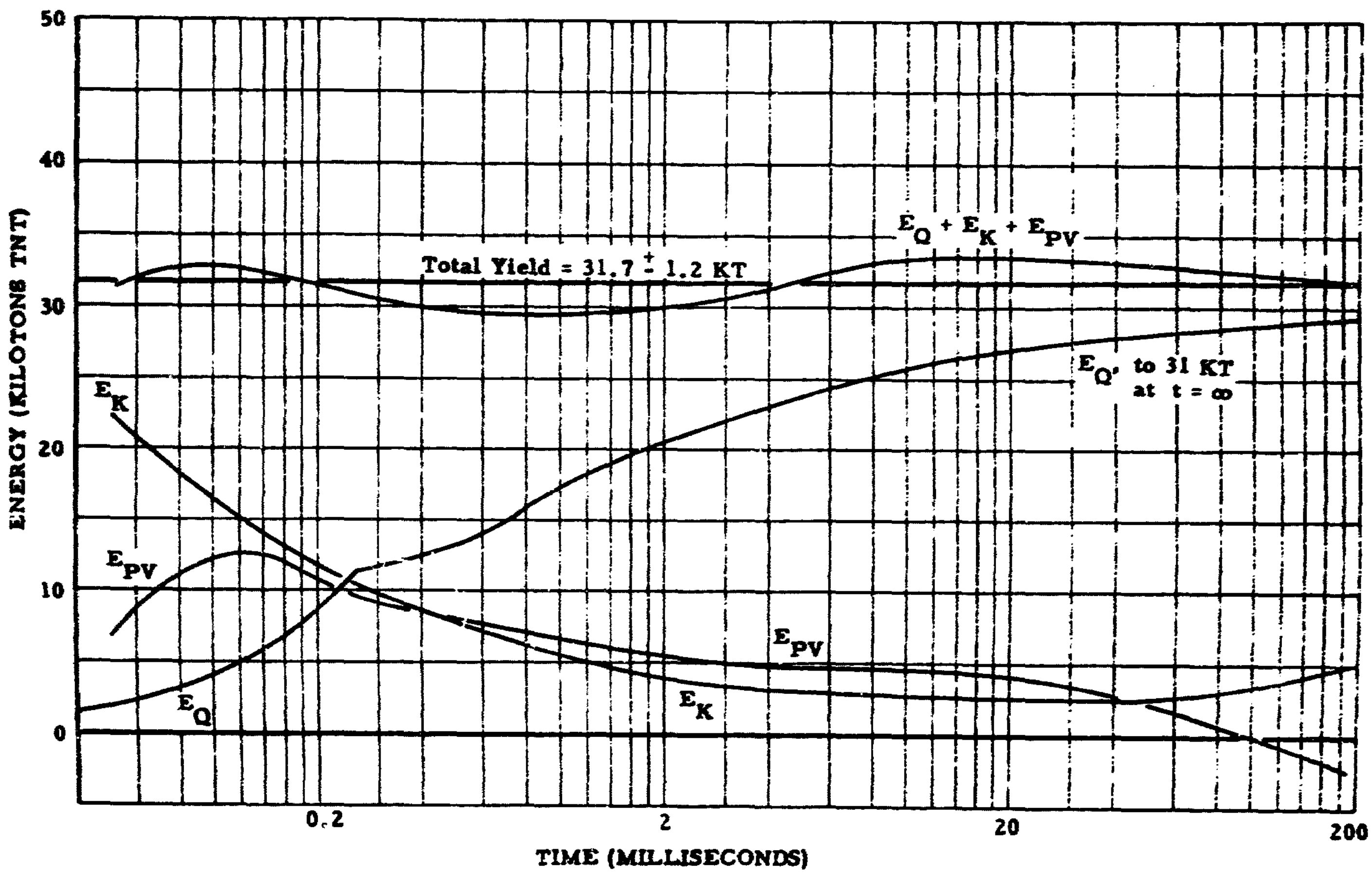
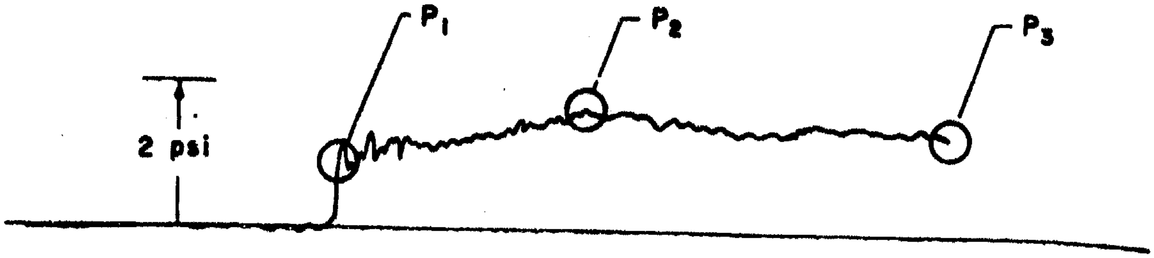
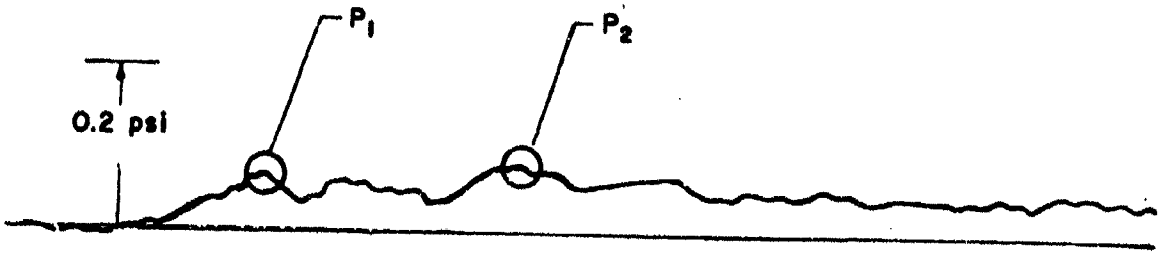


Fig. 3.89—Yield determination.



Gage OMN, surface range 0 ft



Channel 4, surface range 5500 ft

Fig. 3.90—Sample wave forms.

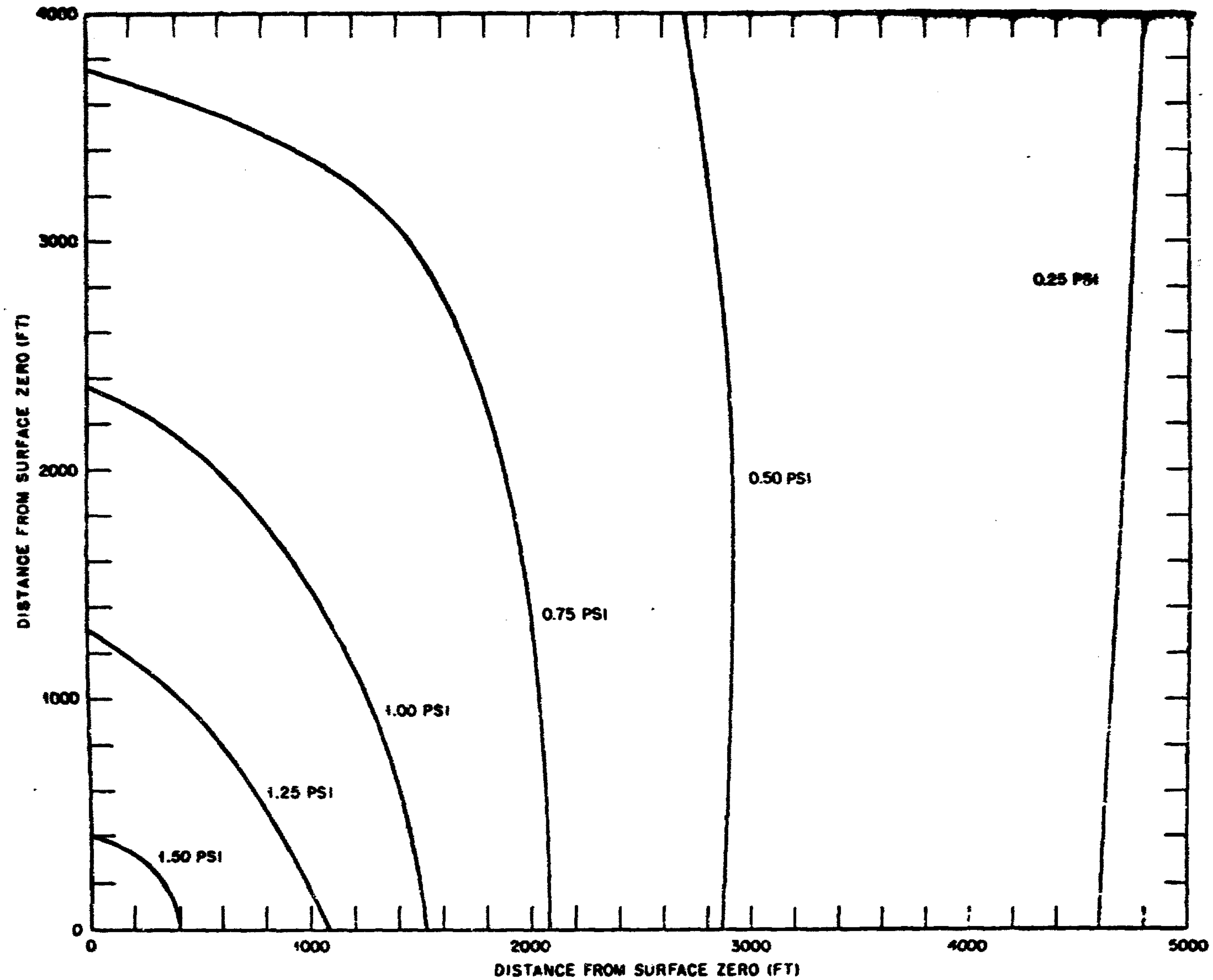


Fig. 3.91—Prediction of air pressures for a Wigwam type burst.

PROGRAM V

TITLE: Timing and Firing (Operation Wigwam, WT-1036, Secret-RD, Michael F. Warchol and Douglas O. Cochrane)

PROGRAM DIRECTOR: B. J. O'Keefe

ORGANIZATION: Edgerton, Germeshausen & Grier, Inc., Boston, Mass., and Las Vegas, Nev.

1. Objectives

a. Provide, install, and operate a timing and firing system capable of performing the following functions:

(1) Transmit via radio, to all users, contact-closure timing signals in a sequence related to the detonation of the deep underwater nuclear device.

(2) Furnish personnel to be members of the firing party.

(3) Transmit arming and firing signals in the proper sequence to detonate the device.

(4) Transmit, if necessary, an emergency "stop" signal capable of stopping the arming and firing sequence at any point down to the last second.

(5) Upon failure of power on the Zero Barge or on receipt of an emergency stop signal, remove power from the firing circuits and acknowledge by transmitting a modulated tone on a d-c-operated transmitter.

(6) Monitor and telemeter by means of a repeat-back system the position of the "arm," "high-voltage," and "fire" relays. Operate an alarm indicator upon leakage of salt water into the bomb case.

(7) Transmit a radio fiducial pulse at the closure of the firing relay and every $1/2$ sec thereafter for the period of $1/2$ hr. Supply users with equipment for receiving these pulses.

b. Determine the time of detonation with respect to world time to within ± 5 msec.

c. Provide and operate an automatic voice countdown system synchronized with the sequence timer to broadcast voice time signals to all units participating in the operation.

d. Furnish, install, and maintain a number of radio communication networks to assist user agencies to accomplish their missions.

2. Results

A radio-controlled timing and firing system was installed and operated. The system was used to supply experimenters with accurate timing signals, in the form of relay-contact closures, during the arming and firing of the deep underwater nuclear device.

The signals were generated by a sequence timer on board the command ship and were transmitted as f-m radio tones which were converted to relay-contact closures by radio-signal receivers at the user's stations.

Separate tone generators and transmitters were used for arm, fire, and stop signals, and a triple set of signal receivers at the zero site was suitably interlocked for maximum reliability.

Monitoring was provided for power loss at the zero site as well as for the arming and firing functions, position of the arm-clock contacts, presence of salt water in the device, and high voltage on the X-unit.

Radio fiducial pips were transmitted to all users requiring them at $1/2$-sec intervals commencing at zero time and continuing thereafter for a period of $1/2$ hr.

World time of the detonation was recorded to ± 5 msec by photographing a specially designed clock at the moment of detonation. The trigger pulse for flashing a high-intensity light was the initial fiducial pip transmitted from the zero station.

An automatic voice countdown system, synchronized with the sequence timer at the control station, broadcast voice time signals to all units participating in the operation.

On the final run the timing and firing system worked perfectly with 100 per cent reception of signals by all users, according to all reports received at the time of writing.

The device was detonated at 19 hr 59 min 59.888 $\pm$ 0.005 sec GMT on 14 May 1955.

PROGRAM VI

TITLE: Photographic Services for Operation Wigwam (Operation Wigwam, WT-1037, Official Use Only, Hal Albert)

PROGRAM DIRECTOR: Hal Albert

ORGANIZATION: 1352d Motion Picture Squadron, Lookout Mountain Laboratory, Los Angeles, Calif.

1. Objectives

Meet the technical and report photographic requirements by utilizing the services of Lookout Mountain Laboratory for:

a. Preparation of scripts for such motion-picture photography as may be authorized.

b. Accomplishment of photography in accordance with approved scripts and in coordination with the test activities to be photographed.

c. The making of all negatives required by other scientific task elements to provide full report coverage for task group scientific programs, units, and staff sections, in black and white, color, still, and motion pictures.

d. The provision of accident and general record coverage.

e. The provision of facilities and aid to project officers in the processing of scientific photographic records.

f. The conduct of necessary aerial photography as required by the scientific programs.

g. The provision of timed photography as required in support of Operation Wigwam.

h. The storage, issuance, processing, and accounting for film in accordance with security and classification restrictions.

i. The accomplishment of complete cataloging and indexing of all film exposed on Operation Wigwam, both still and motion picture.

2. Results

All objectives were met as specified.

3. Recommendations

Considering the many important facets of this type of operation, it is recommended that future operational preplanning include the following as a matter of high priority:

a. Anticipation of subject matter of visual, documentary, technical, or historial interest which should be given photographic coverage and its relative program importance. In this way, photographic priorities can be established, and a photographic plan can be organized and administered to the best interests of operational support and over-all economy.

b. A statement of the command and staff views on photographic support and visual reporting. This would ensure wholehearted support and maximum cooperation from the photographic activity.

Appendix A

SUMMARY OF COSTS BY PROJECTS

TABLE A.1—STATUS OF FUNDS, OPERATION WIGWAM (AS OF 31 JULY 19[illegible])

Program and project	Research and development		Extramilitary (M&O)		Totals	
	Obligated	Expended	Obligated	Expended	Obligated	Expended
0.01	$ 66,140.01	$ 66,140.01			$ 66,140.01	$ 66,140.01
0.02	70,612.58	74,995.94			70,812.58	74,995.94
0.03	23,787.83	23,694.47			23,787.83	23,694.47
0.04 a&b	22,655.18	22,655.18			22,655.18	22,655.18
0.05	109,427.92	109,427.92			109,427.92	109,427.92
0.06	216,747.24	216,747.24			216,747.24	216,747.24
0.07	198,668.31	198,668.31			198,668.31	198,668.31
0.08	34,457.00	34,107.95			34,457.00	34,107.95
0.09			$ 26,461.81	$ 26,515.81	26,461.81	26,515.81
0.10	95,806.64	95,806.64			95,806.64	95,806.64
0.11	99,908.90	99,908.90			99,908.90	99,908.90
0.12	39,979.91	39,979.91			39,979.91	39,979.91
0.13	50,000.00	50,000.00			50,000.00	50,000.00
0.14			21,343.28	21,343.28	21,343.28	21,343.28
0.15	25,457.62	25,457.62			25,457.62	25,457.62
0.16			67,830.83	67,830.83	67,830.83	67,830.83
0.17			122,763.47	122,740.55	122,763.47	122,740.55
0.18			264,803.89	264,413.17	264,803.89	264,413.17
0.19			34,955.28	34,955.28	34,955.28	34,955.28
0.20			12,049.53	12,049.53	12,049.53	12,049.53
0.21			29,576.48	29,576.48	29,576.48	29,576.48
0.22	6,180.96	6,180.96			6,180.96	6,180.96
0.23 a&b			275,990.83	29,990.83	275,990.83	29,990.83
0.24			51,144.72	51,144.72	51,144.72	51,144.72
0.26			4,217.17	4,217.17	4,217.17	4,217.17
0.28			3,648.48	3,648.48	3,648.48	3,648.48
0.29			18,255.79	18,185.18	18,255.79	18,185.18
0.30	3,140.98	3,140.98			3,140.98	3,140.98
0.31			13,890.37	13,890.37	13,890.37	13,890.37
0.33			4,680.12	4,680.12	4,680.12	4,680.12
0.34			29,480.32	29,480.32	29,480.32	29,480.32
0.35			8,172.13	8,172.13	8,172.13	8,172.13
0.36			32,360.52	32,360.52	32,360.52	32,360.52
0.38			2,642.04	2,642.04	2,642.04	2,642.04
0.40			24,260.00	24,260.00	24,260.00	24,260.00
0.41			381,290.00	0	381,290.00	0
Program 0	$1,063,171.08	$1,066,912.03	$1,429,817.06	$802,096.81	$2,492,988.14	$1,869,008.84
1.2a	$ 624,892.00	$ 624,630.30			$ 624,892.00	$ 624,630.30
1.2b			$ 17,256.35	$ 17,256.35	17,256.35	17,256.35
1.2.1	193,169.41	193,169.41	48.60	48.60	193,218.01	193,218.01
1.3a	330,452.81	330,452.81			330,452.81	330,452.81
1.3b			17,667.18	17,667.18	17,667.18	17,667.18
1.4	84,900.43	84,900.43			84,900.43	84,900.43
1.5	56,509.34	53,974.20			56,509.34	53,974.20
1.6	10,000.00	10,000.00			10,000.00	10,000.00
2.1	55,473.00	55,473.00			55,473.00	55,473.00
2.2	10,679.70	10,679.70			10,679.70	10,679.00
2.3	24,843.49	24,843.49			24,843.49	24,843.49
2.4	143,947.41	144,393.99			143,947.41	144,393.99
2.5	125,619.00	125,619.00			125,619.00	125,619.00
2.6	128,518.00	128,518.00			128,518.00	128,518.00
2.7	52,736.71	52,751.74			52,736.71	52,751.74
2.8	83,243.00	83,243.00			83,243.00	83,243.00
Program 1	$1,299,923.99	$1,297,127.15	$ 34,972.13	$ 34,972.13	$1,334,896.12	$1,332,099.28
Program 2	625,060.31	625,521.92			625,060.31	625,521.92
3.1	$ 202,931.24	$ 202,931.24			$ 202,931.24	$ 202,931.24
3.2	15,721.38	15,721.38			15,721.38	15,721.38
3.2.1	17,500.00	17,500.00			17,500.00	17,500.00
3.3	13,737.36	13,737.36			13,737.36	13,737.36
3.4	71,024.37	71,024.37			71,024.37	71,024.37
3.5	95,731.34	95,731.34			95,731.34	95,731.34
3.6	32,975.84	32,975.34			32,975.34	32,975.34
3.8a	1,565,620.68	1,566,924.95			1,565,620.68	1,566,924.95
3.8b	193,190.40	193,190.40			193,190.40	193,190.40
3.9a	115,556.59	115,487.89			115,556.59	115,487.89
3.9b&c			$732,509.44	$731,016.83	732,509.44	731,016.83
Program 3	$2,323,986.70	$2,325,224.27	$732,509.44	$731,016.83	$3,056,496.14	$3,056,241.10

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Program and project	Research and development		Extramilitary (M&O)		Totals	
	Obligated	Expended	Obligated	Expended	Obligated	Expended
4.1a	$ 165,453.48	$ 162,643.72			$ 165,453.48	$ 162,643.72
4.1b			$ 118,730.23	$ 118,550.81	118,730.23	118,550.81
4.2						
4.3						
4.4						
4.5a						
4.5b			5,140.53	5,140.53	5,140.53	5,140.53
Program 4	$ 165,453.48	$ 162,643.72	$ 123,878.76	$ 123,691.34	$ 289,332.24	$ 286,335.06
Program 5	$ 255,360.00	$ 255,360.00			$ 255,360.00	$ 255,360.00
Program 6			$ 99,671.46	$ 95,221.00	$ 99,671.46	$ 95,221.00
Reimbursement to BuShips for loss of reconditional drums			$ 2,250.00	$ 2,250.00	$ 2,250.00	$ 2,250.00
Generator removal from YFNB's 13 and 29			6,796.86	6,796.86	6,796.86	6,796.86
Reimbursement for lost gear, USS Bolster			399.65	399.65	399.65	399.65
Printing test reports (AEC)	$ 30,000.00	$ 19,860.00				
Shipment of net buoys to Norfolk			524.88	524.88	524.88	524.88
Signal electronics equipment			3,680.51	423.59	3,680.51	423.59
Miscellaneous	$ 30,000.00	$ 19,860.00	$ 13,651.90	$ 10,394.98	$ 43,651.90	$ 30,254.98
GRAND TOTAL	$5,762,957.56	$5,753,649.09	$2,424,500.75	$1,797,393.09	$8,197,458.31	$7,550,042.18

Appendix B

EARLY HISTORY OF THE DEEP UNDERWATER ATOMIC DETONATION

B.1 INTRODUCTION

In the interests of making a coherent presentation of a sometimes discontinuous set of events, plagiarism of two basic sources has been freely employed in this Appendix. Much of the material and some of the actual phrases of Dr. W. A. Shurcliff in the Technical Report of Operation Crossroads[11] and of the Historian's Staff who write the Continuing History of the Armed Forces Special Weapons Project[12] have been used.

B.2 EARLY CONSIDERATION OF A DEEP-WATER, DEEP-SUBMERGENCE ATOMIC TEST

The possibility of deep underwater explosions of atomic weapons had been considered almost from the beginning of the atomic bomb project under the Manhattan District. In describing the work of the Ordnance Division at the Los Alamos Scientific Laboratory, on arming and fuzing, in 1944, the Manhattan District History[13] stated:

> In addition to the primary development of a high elevation triggering mechanism, some attention was given to underwater detonation. The goal was to detonate one minute after impact with the surface. This program hardly got underway, however, before theoretical considerations, based on model tests, predicted that shallow underwater delivery was ineffective. Full attention was then given to the air blast bomb...

In discussing the work on the so-called "Super" by the F Division at Los Alamos, also in 1944, the Manhattan District History stated:

> More widespread ground damage would perhaps result from an explosion underground or underwater near a continental shelf. Since it is estimated that a severe earthquake produces energies of the same order as the Super, the surface effects might be comparable. To produce these effects would require ignition at a very great depth, of the order of several miles.

B.2.1 Information Available in 1946

All scientific and military data on atomic explosions available in 1946 came from the three known detonations: Trinity, Hiroshima, and Nagasaki. Although the detonations had been militarily effective, much information remained to be discovered. Some very brief notes on these detonations follow:

(a) *Trinity Explosion*. The Trinity explosion, which took place at Alamogordo, N. Mex., at 1130 on 16 July 1945 (GCT), was a complete success from the military point of view, and much scientific information was gathered, particularly as regards gamma radiation and

neutron radiation. On the other hand, the optical radiation and pressure data were not so extensive as had been hoped.

(b) *Hiroshima Explosion*. The Hiroshima explosion, which occurred at 2315 on 5 August 1946 (GCT), was amazingly successful militarily, but practically no measurements were made of radiation or pressure, and injury-to-personnel data, although extensive, were not fully adequate.

Radiation and Pressure Data. A few photographs were obtained showing the general appearance of the cloud, but none of these permitted qualitative or quantitative analysis of the optical radiation. No measurements were made of the abundance of gamma rays and neutrons emerging from the detonation. Pressure data were obtainable only from radiosondes; these lacked adequate calibration, and their locations (relative to the Zero Point) were not accurately known.

Data on Injury to Personnel. Studies made of injuries to Hiroshima personnel provided a great deal of useful information, particularly as to types of injury; but from the scientific point of view the information was appreciably incomplete.

Nagasaki Explosion. This explosion, which took place at 0158 on 9 August 1945 (GCT), added to the information obtained from Hiroshima, particularly as regards damage to industrial buildings, but it contributed little information on pressure values and radiation intensity, or on the correlation of damage or injury data with pressure data, radiation data, etc.

B.2.2 Interest in a Test Program

Well before the data analysis was completed for the above detonations, public interest arose as to the effects of an atomic bomb on a ship or fleet. On 25 August 1945, Senator Brien McMahon (D., Conn.) made a speech to the Senate in which he suggested using the remainder of the Japanese fleet in an atomic test.

On 18 September 1945, the Army Air Corps recommended the use of the Japanese vessels in an Air Corps atomic bombing test. On 16 October 1945 the Navy recommended that the Joint Chiefs of Staff (JCS) control a joint test under naval supervision. The JCS assigned one of its permanent committees, Joint Staff Planners, to determine what tests were necessary and what agencies should perform them.

B.2.3 Objects of the Tests

In descending order of importance, the following several reasons were determined for conducting tests using Japanese and other vessels:

1. To determine the effects of atomic bombing on naval vessels, naval material, and ships' crews.
2. To provide the Army Air Corps with experience in precision (atomic) bombing.
3. To ascertain the effects of atomic bombing on a variety of army material.
4. To show the kinds and extent of biological and chemical effects produced by radiations of all kinds.
5. To discover successful means of diagnosing and treating persons exposed to radiations.
6. To help answer a variety of hitherto-unanswered scientific questions in the fields of blast, meteorology, radioactivity, oceanography, seismology, radio propagation, and ionization.
7. To determine the remote detectability of atomic bomb explosions.

The Joint Staff Planners recommended that these objects would be best attained by detonating an atomic bomb at each of the following altitudes:

Test A, high in the air (first priority).
Test B, immediately above or below the surface of the water (second priority).
Test C, deep underwater (third priority).

B.2.4 Operation Crossroads

As a result of those recommendations, Joint Task Force One was activated and assigned to accomplish:

> ...the determination of the effects of atomic explosives against naval vessels in order to appraise the strategic implications of the application of atomic bombs including the results on naval design and tactics... The general requirements of the test will be to determine the effects of atomic explosives against ships selected to give good representation of construction of modern naval and merchant vessels suitably disposed to give a gradation of damage from maximum to minimum. It is desired to include in the tests both air detonation and underwater detonation if the latter is considered feasible. Tests should be so arranged as to take advantage of opportunities to obtain the effects of atomic explosives against ground and air targets and to acquire scientific data of general value if this is practicable...

B.2.5 Problems Concerning the Deep-submergence Test

The best depth for Test C (the deep underwater explosion) had never been established. There had been two points of view, one favoring a depth of 1000 ft, the other favoring 1500 to 2000 ft. The principal difficulty anticipated in a deep-submergence explosion was the construction of a bomb container, a coaxial cable, and suitable stuffing boxes, all capable of withstanding the extremely high hydrostatic pressures involved. (Contemporary submarine design, for example, permits submerging to depths of 600 to 800 ft with a safety factor of only 2.) Another limitation as to depth was imposed by the depth of the ocean in the area closely adjacent to Bikini Atoll, and by the desire (in order to avoid complications entailed by reflections from the bottom) to keep the bomb well above the ocean bottom.

Because of technical problems and the long preparations required, cancellation of the deep test was considered. The arguments for holding a deep underwater test were:

> A. Although we now have good information as to what happens when an atomic bomb goes off in air or slightly beneath the surface of the water, we have no clear idea as to what the results would be of detonating an atomic bomb at great depth beneath the surface of the ocean. We have no means of estimating the effects with high accuracy. Conceivably the effects might be significantly greater than expected and might provide data of great military and scientific value.
>
> B. According to some sections of the public, the underwater test would "obviously" be the one which would be most damaging to naval vessels; it would "obviously" be the crucial test, re survival of navies; that test is the one the Navy "obviously fears."
>
> C. The underwater test would show how well the atomic bomb would serve to intercept a hostile fleet approaching our country.
>
> D. Only after we have studied a deep underwater explosion will we be able to interpolate accurately, as in predicting the effects of an explosion at any arbitrary intermediate depth.
>
> E. Some advance preparations have already been made for Test C.

The arguments against holding such a test were:

> A. There is no firm reason for believing that a deep underwater explosion would do more damage than a surface explosion or an explosion at or immediately below the surface; shock effects might not prove to be as overwhelming as some persons expect, and many important atomic bomb effects would be almost entirely eliminated—that is, optical radiation, neutron and gamma-ray radiation, would be almost entirely absent.
>
> B. Concentrations of naval vessels are usually to be found in harbors, but harbors are ordinarily relatively shallow; therefore the deep underwater test would be irrelevant to principal naval targets (i.e., to the commonest concentrations of naval vessels).
>
> C. Even many important ocean areas are very shallow, e.g., the North Sea and the Atlantic Shelf area.
>
> D. Even though in the past there have been many naval vessel concentrations in open (deep) ocean, it would be an obvious and simple matter for future fleet commanders to space their ships very widely—as widely as would be required so that not more than one or two vessels would be put out of commission by one atomic bomb.
>
> E. It would presumably be possible for an enemy in advance of outbreak of war to plant atomic bombs in harbors; and it is conceivable that he would be able to pre-train, say, his V-2

type atomic bomb carriers on our harbors; but no such advance preparations or automatic bull's-eyes would be possible for a deep underwater bomb, i.e., a bomb to be used against a fleet moving in open ocean.

F. Even if an enemy could make bombs usable at great depth he might find it difficult to dispatch the bombs quickly to the particular, deep underwater spot selected. Entirely new techniques and operational procedures would be needed. (If delivery were not made quickly, the target fleet would have time to change course and disperse. If delivery were made by airplane, it is very possible that the airplane would be intercepted and shot down. If delivery were made by submarine, it is quite possible that the submarine would be intercepted and sunk.)

G. An atomic bomb designed for use at great depths would probably be a special-purpose weapon tactically usable only in deep ocean waters. On the other hand an air-burst bomb would be usable the world over, i.e., over cities, armies, harbors, or fleets at sea, and a heavy-impact atomic bomb for delivery by aircraft for underground or underwater detonation would have broad application, particularly for attacking military or industrial concentrations immediately adjacent to bodies of water.

H. Funds and personnel may continue to be scarce.

B.2.6 Cancellation of the Deep Underwater Test

On 7 September 1946, acting on the advice of JCS, the President canceled the test indefinitely:

> In view of the successful completion of the first two atomic bomb tests of Operation Crossroads and the information derived there-from, the Joint Chiefs of Staff have concluded that the third explosion, Test C, should not be conducted in the near future...
>
> The additional information of value expected to result from Test C is such that the Joint Chiefs of Staff do not feel that completion of this test in the near future is justified.

B.2.7 Specifications of a Future Deep Underwater Test

Joint Task Force One stated in the Technical Report of Operation Crossroads that a future deep underwater test should conform to the following specifications:

Depth of bomb:	1000 to 2000 ft*
Depth of bottom:	At least 2.5 times the depth of bomb
Number of target vessels:	Few (or none); by obtaining complete data on pressure, the damage which vessels would suffer could be computed with fair accuracy merely from the damage data obtained in Test B
Number of instruments:	Relatively few; emphasis should be placed on a few well proven instruments very carefully placed, rather than on a great many instruments of uncertain performance placed informally

B.3 INTEREST IN A DEEP TEST REVIVES

Several years passed before interest was aroused once more in a deep-submergence, deep-water atomic detonation. During this period the Armed Forces Special Weapons Project (AFSWP) was assigned, by the Chiefs of the three services, the responsibility for the broadened functions of plans and budgets for the military phases of tests of atomic weapons (17 October 1950). During the summer of 1950, Project Hartwell was set up to make a study of the security of overseas transport. The report of this Project, which was published 21 September 1950, strongly recommended both the development of an atomic depth charge and a deep underwater test to measure its lethal power.

*By using a depth in the neighborhood of 2000 ft, the troublesome radioactive plume and cloud would be avoided.

B.3.1 Pelican Committee Is Formed

On 1 November 1950, CNO requested the Chief, AFSWP, to undertake studies and investigations of problems involved in a test of an atomic detonation at deep submergence and to make recommendations as to the general nature and scope of such a test. On 5 April 1951, a conference with civilian experts and liaison officers resulted in the formation of the (later named) Pelican Committee which was formally organized on 11 May 1951. Its objective was "...to aid the Chief, AFSWP, in arriving at decisions as to whether a deep-submergence test was feasible, as to whether it was necessary, and in what manner it should be conducted if authorized."

(a) *Pelican Committee, Members and Advisers*. A group of experts was chosen, and liaison members from the three services were assigned. The first meeting was held on 16 July 1951. The participants were:

Dr. Arnold B. Arons, Woods Hole Oceanographic Institution, Woods Hole, Mass., Chairman
Dr. Kenneth S. M. Davidson, Stevens Institute of Technology, Hoboken, N. J.
Dr. Gifford C. Ewing, Scripps Institution of Oceanography, La Jolla, Calif.
Dr. Joseph B. Keller, New York University, New York
Dr. Raymond D. Mindlin, Columbia University, New York
Dr. John von Neumann, Institute of Advanced Study, Princeton, N. J.
Dr. Emmanuel R. Piore, Office of Naval Research, Washington, D. C.
Mr. Allyn C. Vine, Woods Hole Oceanographic Institution, Woods Hole, Mass.
Colonel Austin W. Betts, U. S. Army, Army Liaison Member
Lieutenant Commander Robert C. Gooding, U. S. Navy, Navy Liaison Member
Dr. James C. Mouzon, Assistant for Operations Analysis, United States Air Force, Air Force Liaison Member
Dr. Hans H. Bleich, Columbia University, New York, Consultant, Target Response
Dr. Alfred B. Focke, U. S. Navy Electronics Laboratory, San Diego, Calif., Consultant, Instrumentation

The Secretariat consisted of (all of AFSWP):

Captain Howard B. Hutchinson, U. S. Navy, Executive Secretary
Captain William B. Taylor, U. S. Army, Assistant
Mrs. Martha K. Holmes, Secretary

Panels were formed in particular fields of interest:

1. The Panel on Free Field Effects, consisting of Drs. Keller, von Neumann, and Arons.
2. The Panel on Target Response, consisting of Drs. Mindlin and Davidson and Lieutenant Commander Gooding, retaining Dr. Bleich as consultant.
3. The Panel on Instrumentation, consisting of Drs. Piore and Mouzon, retaining Dr. Focke as consultant.
4. The Panel on Oceanography, consisting of Dr. Ewing and Mr. Vine.

Contributions were received on different facets of the general problem from many groups and individuals:

1. NOL, BuShips, BuOrd, and ONR representatives covered current and projected research in various fields of underwater explosions.
2. Dr. Curtis W. Lampson of the Ballistic Research Laboratories, Dr. A. B. Arons of Woods Hole Oceanographic Institution, Dr. A. H. Keil of the Underwater Explosions Research Division, Dr. E. H. Kennard of the David Taylor Model Basin, and Dr. H. G. Snay of the Naval Ordnance Laboratory presented the current status of knowledge of the primary characteristics of atomic explosives in air and water; target response to underwater explosives; and model scaling techniques.
3. Dr. W. G. Penney of the Armament Research Establishment gave a British perspective to the Committee's approach.
4. Mr. J. Paul Walsh of the Naval Research Laboratory discussed the damaging effects of underwater shock on submarines.

6. Commander C. N. Hendrix, U. S. Navy, and Captain C. W. Shilling, U. S. Navy (MC), explained physiological and neuro-psychiatric effects of depth-charge attacks on submarine crews.

When the Pelican Committee was dissolved, all members except the liaison officers of the Army and Air Force were invited to remain as consultants to the Chief, AFSWP. Two consultants to the Committee itself, Dr. A. B. Focke and Professor Hans H. Bleich, were also retained as consultants.

(b) *Questions the Pelican Committee Sought to Answer*. In accomplishing its objective the Pelican Committee studied the following questions:

1. What is the best prediction of the lethal range of a deep-submergence atomic weapon against submarines of various types under various conditions?
2. How well can this lethal range be estimated from the present knowledge of underwater explosions?
3. To what extent would a full-scale test improve this estimate?

In addition to providing answers to these questions, the Committee's objective included:

1. A determination of the feasibility of conducting a full-scale test.
2. Positive or negative recommendations regarding the authorization of a full-scale test.
3. Ways and means of conducting the test, if a test was recommended.

(c) *The Pelican Report*. On 10 April 1952 the Pelican Committee concluded its activities and presented an elaboration of the following recommendations in a published report:[14]

> ...That a full-scale test be conducted as soon as adequate pressure-time instrumentation is available; which now appears to be at the end of a two-year period of developing and testing, if the highest priority is attached to such a program.
>
> ...The Committee recognizes the possibility that subsequent tests may be necessitated by the results obtained from the proposed test, and it also recognizes the possibility that urgency might direct an earlier test. If an earlier test should be directed, the Committee feels that certain valuable information would be sacrificed but that some pertinent information could be gained...

B.3.2 *Ad Hoc* Committee of Professional Officers

On 15 July 1952, the Chief, AFSWP, was requested by CNO to form an *ad hoc* committee with a view to determining:

> A. The feasibility from the standpoint of seamanship and expense of conducting the test.
>
> B. Whether or not, in connection with the Pelican Report, sufficient information on the effects of underwater detonations can be determined or predicted from a test of lesser magnitude than that proposed.
>
> C. The date and geographical location for conducting any test proposed by the Committee.

(a) *Ad Hoc* Committee, Members and Advisers.

The *Ad Hoc* Committee and its secretariat were composed of the following members:

Rear Admiral W. K. Mendenhall, Jr., U. S. Navy, Headquarters, AFSWP, Chairman
Captain W. T. Nelson, U. S. Navy, Bureau of Ordnance
Captain V. B. Cole, U. S. Navy, Bureau of Ships
Captain J. I. Cone, U. S. Navy, Naval Ordnance Laboratory
Colonel F. J. Clarke, U. S. Army, G-4, Department of the Army
Colonel T. Drysdale, U. S. Air Force, AFOAT
Commander W. W. Walker, U. S. Navy, Chief of Naval Operations (Op-36)
Commander K. S. Brown, U. S. Navy, Bureau of Ships
Lieutenant Commander E. V. Mohl, U. S. Navy, Hydrographic Office
Captain H. B. Hutchinson, U. S. Navy, Headquarters, AFSWP, Executive Secretary
Captain W. B. Taylor, U. S. Army, Headquarters, AFSWP, Assistant

The following, on invitation of the Committee, were present as official observers at two or more of the meetings and participated in the work of the Committee:

Captain E. O. Wagner, U. S. Navy, Office of Naval Research
Dr. A. B. Focke, U. S. Navy Electronics Laboratory
Mr. J. W. Smith, Office of Naval Research
Lieutenant Commander R. C. Gooding, U. S. Navy, David Taylor Model Basin
Dr. H. T. Wensel, G-4, Department of the Army

(b) *A Formulated Test Objective*. In order to consider feasibility and magnitude problems, the *Ad Hoc* Committee found it necessary to establish the following formal objective for the test:

> The military objective of an underwater test of an atomic weapon is to determine with satisfactory accuracy at what ranges under varying conditions one may kill an enemy submarine and at the same time insure the safety of the delivery vehicle and its supporting force. Implied in this objective is the necessity for determining the lethal range of a deeply submerged atomic weapon of known yield under known conditions in order to obtain data which can be applied to other yields and other conditions.

(c) The *Ad Hoc* Committee's Conclusions. In accordance with its directive, the Committee arrived at the following conclusions:[18]

1. A deep underwater test of an atomic weapon was feasible from a standpoint of seamanship. An adequate target and instrument array similar to that indicated in the Pelican Report could be handled under selected conditions of wind and sea. This could be accomplished by any of four methods, which were outlined in the final report of the Committee.

2. The estimated cost of the proposed test was given as $32,115,230. (This figure was later estimated to be nearly $36,000,000, by the AFSWP Weapons Test Division, from their previous experience in conducting atomic tests.)

3. The magnitude of the test could be reduced slightly from that indicated in the Pelican Report without serious prejudice to the objective of the test.

4. The committee concurred with the recommendation in the Pelican Report that a nuclear device of an equivalent energy release of about 20 kt, detonated at 2000-ft submergence in deep water, should be used in the test.

5. The best sites for conducting the test lay in the Panama–Cape Mala–Galapagos Islands area, bounded roughly by latitudes 2°S and 8°N and by longitudes 77°W and 93°W. The best date for conducting the test in this area was regarded as February 1955. The Committee also selected the following areas and seasons, in order of preference, as alternatives to the principal selection:

a. The area to the west of Mexico in the vicinity of Guadaloupe Island, during the period of June through October.

b. Areas in the Caribbean Sea to the westward of Guantanamo Bay and the Gulf of Guacanayabo, and also areas to the southward of Vieques Island and the eastern end of Puerto Rico, during the period of January through June.

c. Areas near Bikini and Eniwetok Atolls, during July and August.

The Committee concluded its activities on 25 September 1952, and its report was transmitted to CNO on 12 October 1952.[5]

B.4 TEST PREPARATIONS BEGIN

On 23 October 1952, the Committee on Atomic Energy of the Research and Development Board also pointed out the desirability of conducting a deep underwater test. On 8 December 1952, the Joint Chiefs of Staff formally recognized the need for such a test, and the AFSWP was directed to begin its planning and preparation.

B.4.1 Special Projects Division of Headquarters, AFSWP

Chief, AFSWP, initiated formation of a planning group on 16 December 1952. The Special Field Projects Division began operating on 5 January 1953, and CNO assigned the code name Operation Wigwam to its activities on 14 January 1953.

After some modification, the permanent group formed, which was intended to follow Operation Wigwam through to completion, included:

Special Assistant to the Chief, AFSWP:
Rear Admiral John Sylvester, U. S. Navy
Chief of the Division:
Captain James R. Z. Reynolds, U. S. Navy
Scientific Director:
Dr. Alfred B. Focke
Logistics Branch:
Captain James R. Z. Reynolds, U. S. Navy
Technical Operations Branch:
Captain John H. Lofland, Jr. (CEC), U. S. Navy
Lieutenant Colonel George F. Watkins, U. S. Air Force
Commander David R. Saveker, U. S. Navy
Operations and Planning Branch:
Commander Charles A. Bellis, U. S. Navy

(a) *Duties of the Chief of the Division*:

1. To report to and advise the Deputy Chief of Staff, Technical Services, on matters pertaining to the planning, preparation, and budgeting for the conduct of a special test.
2. To supervise the activities of the Logistics Branch, Operating and Planning Branch, and Technical Operations Branch, and to formulate policy relative to the functioning of these units.
3. To provide over-all guidance to the Scientific Director for purposes of coordination.

(b) *Duty of the Scientific Director*:

To supervise and guide the technical phases of planning and preparing for the special test assigned to the Division.

(c) *Duties of the Logistics Branch*:

1. To control the following functions within the Division: budgeting and fiscal, supply and procurement, transportation, construction, and engineering.
2. To maintain pertinent liaison with the services, with technical bureaus, and with divisions within the AFSWP.
3. To perform such other duties as might be assigned.

(d) *Duties of the Operations and Planning Branch*:

1. To prepare preliminary plans for the conduct of the operational phases of the test and for the coordination of service participation in such phases.
2. To conduct investigations and evaluation of the various operational techniques required for the conduct of the test.
3. To maintain pertinent liaison with the services, with technical bureaus, and with divisions within the AFSWP.
4. To perform such other duties as might be assigned.

(e) *Duties of the Technical Operations Branch*:

1. To plan and prepare for the conduct of the technical programs associated with the special test.
2. To coordinate service participation in the technical programs.
3. To coordinate the participation of the AEC and its contractors, of government agencies, and of research laboratories in the technical phases of the test.
4. To perform such other duties as might be assigned.

B.4.2 Original Objectives of Operation Wigwam

The major test objectives of Operation Wigwam were as follows:

1. To obtain data on which to base the optimum yield of atomic depth bombs or charges being currently designed and developed.

2. To ascertain the lethal range of atomic depth bombs or charges against submarines and surface ships, particularly from the points of view of hull splitting and internal shock damage.

3. To determine the relative effectiveness of the atomic depth bomb or charge against surface ships in convoy and task force formation, as compared to air or surface burst.

4. To obtain information on which to base safe delivery tactics of the atomic depth bomb or charge.

These objectives had been formulated, in the main, by the *Ad Hoc* Committee of officers in their deliberations concerning feasibility and cost. Ancillary objectives included such studies as effects on marine biology, scientific measurements of the effect on the nuclear explosion of the deep underwater detonation, oceanographic phenomena associated with the explosion and residue, problems of long-range detection, and recording of the pressure-time history of the shock wave in water and air.

B.4.3 Problems Facing the Wigwam Planning Group, January 1953

(a) *Scope of Test*. How much money was going to be available for how many and what kind of ships for how much of a scientific effort?

(b) *Project Proposals*. Who was going to do what and to what extent in achieving the test objectives?

(c) *Preliminary Studies*. *Targets*. What types should be used, who will construct them and how, how are they to be handled and operated, and how are their behavior and quality as instruments to be known and predicted? What preliminary tests should be made and who will make them?

Detonation Area. Where should the weapon be detonated?

1. Oceanography: What are the pertinent oceanographic conditions of the chosen area and to what extent may they be predicted?

2. Contamination: What radiological contamination will result, where will it go, and what will it affect?

3. Meteorological: What are the pertinent meteorological conditions of the chosen area, and to what extent may they be predicted?

Operations. What is the best type of array to use, and what is the best method for coupling units and for fixing the array position? What tests and trials are necessary? What coordination is necessary with what operational activities? What special equipment should be acquired or made?

(d) *Administration*. What type of organization would be most effective? What specific responsibilities should be assigned to whom in the staff? What security problems exist, and what steps should be taken? What logistic support is required, and what are the sources of funds and how are they to be accounted?

B.4.4 Scope of Test

(a) *Original Test*. Attainment of the original objectives was estimated to cost:

Extramilitary	$23,270,000.00
Research and development	13,250,000.00
Total	$36,520,000.00

exclusive of any target-ship replacement costs. (Research and development funds were used to support all projects classified as scientific. Extramilitary funds supported military commands for participation in the Operation that involved other than their normal schedule of activities and related financial allotment.)

Approval for expenditure of the research and development funds was requested from the Chairman, Research and Development Board, on 28 January 1953. The request and the program were approved without change on 18 March 1953.

(b) *Test Reduced*. By this time the new administration was reviewing all programs of current and high cost. Investigation by the Office of the Secretary of Defense and the National Security Council finally resulted in the AFSWP being requested by the Assistant Secretary of Defense (Atomic Energy) on 13 April 1953 to determine if economies could be made in the proposed test, including target-ship replacement costs.

In reply, the Chief, AFSWP, stated that a minimum Operation Wigwam, much reduced in scope, had been considered. Such an operation would involve a preliminary series of scaled high-explosive experiments, followed by a full-scale nuclear test with only two submarine targets at a single depth and at ranges determined by the high-explosive series. This program would provide a reasonable assurance of reducing the current uncertainties on target response and would provide basic data on underwater and air shock. It was emphasized that such a test would provide no information on surface-vessel response, internal shock damage, and variations of lethal range with depth. The estimated cost of such an operation was $9,300,000, a reduction in total emergency-fund budgeting of $27,220,000, and some $220,000,000 in target-ship replacement costs.

The test objectives under this reduced program covered: hull response of just two submerged targets, free-field air and water measurements, weapon-yield and radioactivity-dispersion determinations, and evaluation of surface effects with particular regard to their influence on delivery tactics.

(c) *Concern for Adequacy — Test Scope Broadened.* On 21 July 1953, the Special Assistant to the Secretary of Defense stated that the reduction had caused concern about the adequacy of the reduced test. The Chief, AFSWP, replied that an additional target was recommended.

On 16 November 1953 the Chief, AFSWP, was directed by the Deputy Assistant Secretary of Defense (Research and Development) to request additional funds for a third submerged target. The request was made on 24 November 1953, and on 8 December 1953 the Secretary of Defense approved the increase. The new total was $12,280,000.

B.4.5 Project Proposals

(a) *Specific Requests from AFSWP.* Initial requests from AFSWP (Wigwam Plans Group), on 21 May 1953, initiated several programs:

1. BuShips was requested to conduct a design study to determine the most suitable type of float for the purpose of instrumentation and target support; make recommendations in the determination of the most suitable type of float; provide plans and contract for the construction or modification of the floating equipment decide upon, subject to final decision by the Chief, AFSWP; approve the use of lighters, or similar craft, if study results indicated such craft would be suitable.

2. Ship Design Division, BuShips, was requested to make target-evaluation studies leading to the selection of the type of submerged target best suited to the objectives of the test.

3. NEL was requested to submit proposals for (1) a free-field instrumentation system which would be a prototype of a complete station in the target array and (2) the conduct of target-response studies using high explosives. The response studies were to augment work already being done at UERD, Norfolk Naval Shipyard, and at DTMB.

4. DTMB was requested to submit a proposal for evaluating the various proposed handling techniques, using scale models, so as to determine the most feasible and economical method of forming the target array, lowering and raising submerged targets, and handling instruments and instrument floats within the array.

(b) *Participation Invited by AFSWP.* By mid-July 1953 a preliminary outline of the desired test proposals had been formulated. The three services and the AEC were formally invited to review the program and project summary and to submit proposals covering the outlined projects. The Army replied that its interests were being adequately met by the out-

lined programs, and therefore no proposals would be submitted. The Air Force stated that its interests and participation would be centered primarily about analysis of radioactive samples and long-range detection. The AEC, through the Director of Military Application, stated that it was prepared to provide a weapon of the desired yield and to undertake other limited projects, including determination of yield through radiochemistry. Furthermore, if AFSWP requested, close-in time-of-arrival measurements and air-blast measurements would be made. AFSWP accepted the major points of all AEC proposals. Naval interests were satisfactorily covered in the preliminary outline. At this stage, the preliminary work of the operation began; this is covered in Chap. 1 of this report.

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